DISCOVERY

THE PROGRESS OF SCIENCE

EINSTEIN IS SEVENTY-FIVE
Dr. J. Bronowski

TIONAL INSTITUTE F OCEANOGRAPHY
Chapman Pincher

PAUL EHRLICH (1854-1915): FATHER OF CHEMOTHERAPY
H. O. J. Collier, *Ph.D.*

THE ATOMIC SUBMARINE

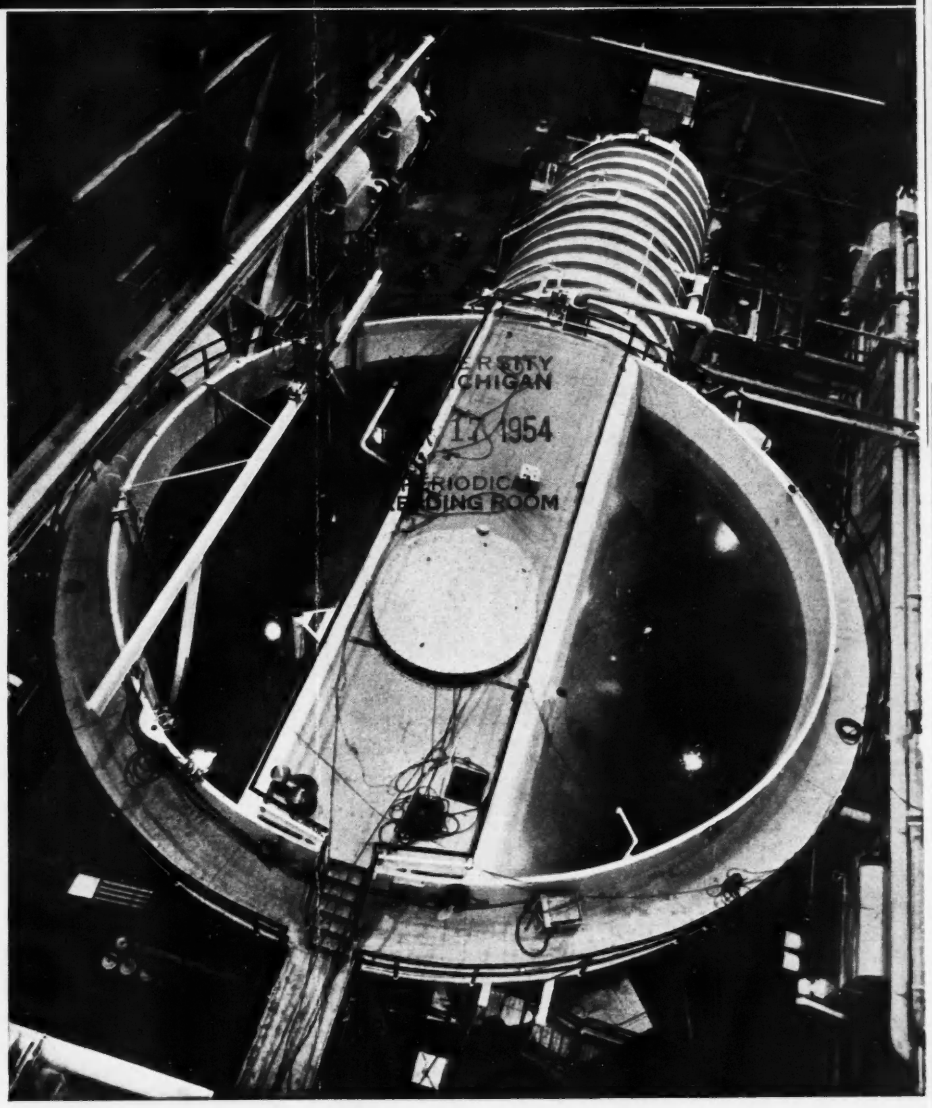
THE CAUSES OF EXTINCTION
W. E. Swinton
Ph.D., F.R.S.E.

ILMING BADGERS AT NIGHT
R. Hewer & E. G. Neal

MAN'S ECONOMIC TEREST IN PLANTS
William E. Dick
B.Sc., F.L.S.

FAR AND NEAR

THE BOOKSHELF

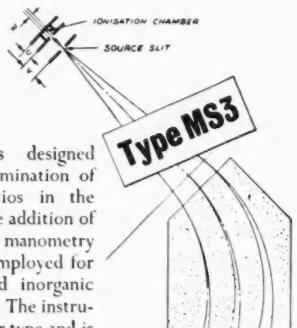


Land-based prototype of STR engine for the atomic submarine.

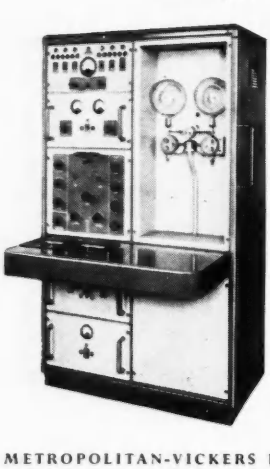
MARCH 1954 **2/-**

NEW

METROVICK
Mass Spectrometer



This instrument was designed primarily for the determination of isotope abundance ratios in the mass range 1-70. By the addition of a newly developed gas manometry system it can also be employed for analysis of organic and inorganic gases in the same range. The instrument is of the 90° sector type and is suitable for use by operators of moderate experience. Selection of ions of a given m/e ratio is made by manual adjustment of the ion-accelerating voltage and the magnetic field is pre-set by means of a rotatable permanent magnet.



Details of the MS3 Mass Spectrometer are given in leaflet 905/12-1 which will be forwarded on request.

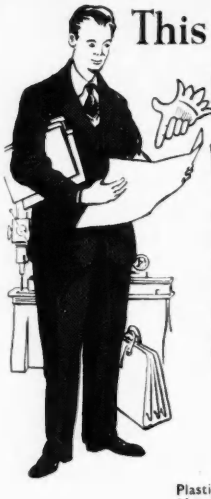
In the magnetic field, ions of any one m/e ratio travel on one circular arc and those with a different m/e ratio travel on another. The Metrovick MS3 Mass Spectrometer is simple and straightforward in operation.

METROPOLITAN-VICKERS ELECTRICAL CO. LTD.
TRAFFORD PARK, MANCHESTER, 17. *Member of the A.E.I. group of companies*

METROVICK

Applying Electronics to Industry

NA/201



This BLUEPRINT is Morane* PROTECTED

Cut your costs by protecting Blueprints, Notices, Documents, Bookcovers, Charts, Drawings and all printed matter with Morane Transparent Heatsealing Plastic Skin.

- Washable high gloss surface
- Instantaneous firm bond to paper, cardboard, etc.
- Can be fixed by unskilled labour

Plastic material now available for lamination of identification cards, calendars, price tickets, etc.

SEND NOW FOR FULL DETAILS OF

*Morane Transparent HEATSEALING PLASTIC SKIN

MORANE PLASTIC CO. LTD.
21 WOODTHORPE ROAD · ASHFORD · MIDDLESEX
Telephone: Ashford (Mx.) 2727/3391

CRACK DETECTION
assured by Fluorescence

Positive, immediate detection of cracks, flaws or leaks in components is made possible by the Hanovia portable Fluorescence lamp Model 16. This unit throws a powerful beam which even in semi-daylight gives brilliant fluorescence effects at distances up to several feet. Write now for details and literature to:

HANOVIA

HANOVIA LTD · SLOUGH · BUCKS

T62

DISCOVERY

THE MAGAZINE OF SCIENTIFIC PROGRESS

Editor WILLIAM E. DICK, *B.Sc, F.L.S.* *Editorial Office* 244 High Holborn, WC1 Chancery 6518
Subscription, distribution and business communications to Jarrold & Sons Ltd, Norwich Norwich 25261
ADVERTISEMENT OFFICE Aldridge Press Ltd. 27 Chancery Lane, WC2 Holborn 8655

MARCH 1954 VOLUME XV NUMBER 3

THE PROGRESS OF SCIENCE

THE REITH LECTURES AND THE DEFECTS OF SCIENTIFIC COMMUNICATION

The controversy about Dr. Oppenheimer's Reith Lectures has proved rather futile, and we certainly hope that the B.B.C. will not follow the suggestion that the Reith Lectures should be made 'more popular'. Reith lecturers should perhaps strive to achieve a higher degree of intelligibility, but they should not be asked to dilute their talks to the level of predigested pap that anyone could imbibe without effort. Oppenheimer's lectures did, of course, reveal a significant paradox, which is, however, commonly experienced these days. The paradox we refer to is this: many a sixth-form boy found no difficulty in following Oppenheimer's ideas, whereas his parents were quite out of their depth. The reason is a very obvious one: science has been developing too fast for many people to understand where it has got to. This difficulty, however, cannot be met by making the Reith Lectures more popular. That would be like asking Vaughan Williams to write songs for crooners.

So far as talks in general are concerned, radio has a lot of 'growing up' to do. It has a long way to go before it can be recognised as a *mature* medium for communicating ideas (as opposed to the relatively simple announcing of facts). It has yet to acquire that indispensable quality of adult discussion which is implicit in the term 'freedom of speech', and it has yet to prove that it is capable of being used to explain a relatively complicated nexus of facts and ideas in a way that leaves a deep impression of lasting value to the listener. The Reith Lectures represent a praiseworthy experiment in the right direction, and they give a hint of the power and the limitations of serious radio talks when they are designed to present to listeners the spoken thoughts of a brilliant individual. It is better, we believe, that the Reith lecturer should not be restricted as to his subject-matter, nor should he be made to conform to normal production methods, which are only applicable to radio programmes designed for 'the average listener'. The language and level of presentation should be the lecturer's own choice, not that of a professional radio producer.

Whether modern scientific ideas can be conveyed satisfactorily under such conditions, no one knows. The experiment of the Reith Lectures is far too young for that question to be answered, even tentatively, and it is unlikely whether the B.B.C.'s Listener Research unit has any relevant information on which one might begin to frame an answer.

* * * *

The general problems that arise when 'mass media' are used to propagate new scientific ideas and to announce the facts about new discoveries were profitably discussed in a recent issue of the American *Bulletin of the Atomic Scientists*. In it a number of writers and scientists gave their views about science and the Press, and it was a pleasure to find so much agreement between the two sides and so little disagreement. In the U.S.A. the scientists and journalists get on very well together, a fact that is very obvious when one reads the American newspapers, which generally give an excellent coverage of scientific news.

In this symposium on Science and the Press, the shortest and most stimulating contribution was made by Philip Wylie, the novelist and essayist. He sees any differences between the scientists and journalists as reflections of two major cultural defects in modern society.

Firstly, a mass circulation newspaper tends to concentrate on that type of news which the largest number of people will most readily buy. The publishers of such newspapers, suggests Mr. Wylie, tend to be men of such poor education that "the whole of basic science is uncomprehended by them", and if editorial policy is dictated by such men then science stands a poor chance of being reported since their policy boils down to "If John Smith cannot be made to understand it, then it isn't news." Such a newspaper would probably print columns by scientific 'quacks' as readily as responsible scientific information: "they print horoscopes and astrological data alongside twentieth-century findings!" This approach is an obsolete one, in that it contradicts the undisputed fact that a modern community rests upon the application of scientific knowledge for most of its daily living, for its economic wealth, its welfare, its military power and so on. That is the gist of

Mr. Wylie's case against the bad newspaper, which would be bound to remain a bad newspaper because only the worst pressmen would be prepared to work under a proprietor of that type. (Fortunately for Britain, such proprietors are virtually non-existent, because of the intense competition that exists whenever a small country like ours has the free choice of a large number of newspapers.)

Mr. Wylie then proceeds to consider the failings on the scientific side. He indicts the 'ivory tower' attitude, which has served its purpose and is today completely obsolete. Science today has the freedom to proceed in any direction and it is able to 'think' as abstractly as it can. All scientific knowledge is "a merely human artifact, a brain-formed structure which attempts to reflect or simulate reality", and therefore science must be regarded as *knowledge for man's sake*, since it is entirely *of* and *for* his doing. Regarded in this light, as an essential human function, science must be communicated at least widely enough so that society will permit research and hypothesis to be a continuing process. "To know something true without teaching it (the extreme of the scientific ideal I here hold to be obsolete) is merely advanced megalomania or, in other words, the most pernicious form of infantilism. It is absurd of scientists to regard themselves as detached and unemotional and to express that self-view by the utterly unscientific technique of pure arrogance, a pure emotion," comments the writer.

Scientific thought being a totally human phenomenon, the scientist therefore owes complete communication of his findings to the public, of which he is part even in his most 'scientific moment'. It is up to the scientist to be as explicit as possible about his discoveries, *regardless of whether his information is distorted or scandalously exploited by the Press.* Mr. Wylie stresses the point that all 'freedom' depends basically on an absolute freedom to know, and suggests that "scientists who strive toward truth have a better chance of soon catching onto the idea than publishers whose main goal is paper sales".

The last words of Mr. Wylie's article are equally pithy and to the point: "Perhaps it would help if every scientist realised that the reporter who questions him is not a fool but merely a man who feels intensely inferior. Certainly, knowledge for the final sake of annihilation would add up to a feeble achievement of the human mind!" Conscious as we are of our own ignorance, we certainly agree that there is a social compulsion binding upon both scientists and journalists to compose their differences: it is part of their duty to the public at large.

ELECTRICAL BIRD-WATCHING

The difficulty of keeping continuous watch on the nest of a wild partridge throughout a 24-hour day and so obtaining accurate knowledge of the movements of the sitting hen bird, has been overcome by workers at the I.C.I. Game Research Station at Fordingbridge, in Hampshire, by means of an electric recording device. Such knowledge is of importance to gamekeepers since the length of her absences from the act of 'sitting' and incubating the eggs determines how long the eggs take to hatch.

Thus one finds that it is a common belief amongst gamekeepers that the wild partridge will often take 28–30 days to incubate her clutch of eggs, although the normal incubation period is 23–24 days.

The recording device consisted of a simple make-and-break switch operated by the pressure of the sitting bird. The long switch lever was placed in the nest, and the electrical contact was made by the depression of this lever by the weight of the bird when she was sitting in the nest. As soon as she moved off the nest, a spring returned the lever to the normal undepressed position and the contact was broken.

The record of the time spent sitting on the nest was recorded by means of a stylus writing on a kymograph drum placed at some distance from the nest, and the information about the bird's movements was led from the switch to the recording apparatus by means of a twin wire cable. Power was supplied by a 6-volt 100-amp. car battery. Although the recording machine was placed at a distance from the nest and so created little disturbance, it was found to be advisable to camouflage the switch apparatus placed in the nest and this was done by painting it with quick-drying adhesive and gluing on small particles of earth and grass so as to make it blend with the nest materials.

Recordings taken with the device showed that weather is a major factor in determining the consistency of the sitting of the parent hen bird.

In cold and generally unpleasant weather the bird left the nest at frequent intervals, although only for short periods of time, while in warm, mild weather the bird left the nest less frequently. On the other hand when the hen did leave the nest in warm weather, she tended to be absent for longer periods of time.

Observations over the egg-laying period prior to incubation showed a remarkable consistency in the time spent over the actual process of laying. In each case the laying of the eggs took approximately 45 minutes with a range of variation in the time taken of only $\pm 10\%$.

There was, however, some variation in the time that the hen bird actually started to sit and incubate her eggs after laying them and arranging them in a 'sitting' position. For example, one bird did not commence sitting on the eggs until three days after she had moved the eggs into the normal position in which they are arranged when incubation is about to commence—thus explaining the discrepancy in time of incubation observed by the gamekeepers.

REFERENCES

R. J. Fant, "A Nest-recording device", *The Journal of Animal Ecology*, 1953, Vol. 22, No. 2, pp. 323–7.

IAN—THE CABBAGE HORMONE

Plant hormones are being studied by many plant physiologists, organic chemists and biochemists all over the world, and this kind of research has been intensified since the development of practical applications for certain such substances in agriculture and horticulture. A general account of their present uses and the potential extension of their application was given by Prof. S. C. Harland in his Fenhurst Lecture (DISCOVERY, November, 1953, pp. 350–4).

It was about twenty years ago that a group of Dutch

workers isolated a substance—then called *hetero-auxin*—which is highly active in promoting cell elongation in stem tissues from malt oils and from urine. This substance was identified as 3-indolylacetic acid. Later this acid was found to affect many other phases of plant growth. For example, at the same concentrations which stimulate stem growth, it *inhibits* the growth of roots. On the other hand, it *promotes* the formation of roots *on stem tissue*. It also has the property of inhibiting the development of lateral buds. There is some evidence to support the view that it may affect the changes which result in a plant shoot coming into the reproductive phase.

This acid and its ethyl ester have been isolated in crystalline form from seeds. The presence of hormones in the roots, stems and leaves of actively growing plants has been accepted almost as an axiom in spite of the fact that no growth hormones had been isolated from such material until quite recently.

One of the most vigorous teams of botanists and chemists working in this field is the one at Manchester University. Their search for the hormone or hormones present in green plants was no simple matter, for it could be assumed that this substance or substances would be present in very low concentrations—too low to enable them to be picked up by conventional chemical and physical methods of analysis. Bio-assay techniques had to be used instead. In a bio-assay, the extract suspected of containing an active substance is tested on a living tissue or organ capable of giving the required response if the hormone is present. The Manchester team favoured the following method of bio-assay*: the living material on which their tests are based is the oat coleoptile (the leaf which forms a protective sheath around the first shoot put out by the germinating seed), which is first decapitated and then cut again to yield a segment 10 millimetres long; these segments are kept in the test solutions for a standard period of time under standard conditions of temperature, light, humidity, etc. The resultant elongation of the segments is then measured by means of a microscope with a micrometer eyepiece.

There is a relationship between the concentration of a hormone in the test solution and the elongation produced; the elongation is approximately proportional to the logarithm of the concentration within certain limits. This relationship can be standardised by calibration against the effects obtained with known concentrations of synthetic hormones—that is, hormones of known chemical composition prepared in the laboratory.

Of course, in all work involving growth of living organisms there is variation between individuals in response to a given stimulus. Bio-assays are therefore carried out using a number of individuals (replicates) for each treatment, and a mean response is obtained. Even so, there is often large variation between batches tested on different occasions with the same treatment, and one of the main aspects of bio-assay technique is to be able to handle this variation statistically and to understand its significance when unknown treatments are being given.

Using a standardised technique to measure cell-elongation, it was discovered at Manchester that plant extracts which were neutral, and which evidently did not contain free 3-indolylacetic acid, were highly active. This indicated the presence of a new hormone. The materials examined were all members of the Cruciferae family—radish, cauliflower, swede, turnip, brussels sprouts and cabbage; subsequent examination of plants from other families never revealed such high activity. It was therefore decided to concentrate on the cabbage, since this gave highly active extracts and was available in large quantities.

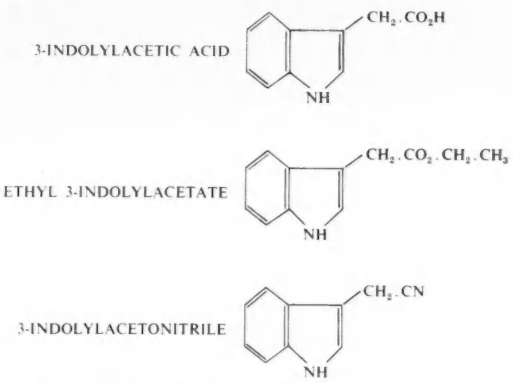


FIG. 1. This diagram shows the chemical relationship of IAA and IAN, two naturally occurring plant hormones or auxins.

The extracts were prepared by a standardised technique using organic solvents (e.g. ether or carbon tetrachloride). Every effort was made to freeze the plant material immediately it was removed from the ground, and the extractions were carried out at a low temperature, usually 0–2°C. The procedure was adopted to prevent the breakdown of hormones present in the tissues during the period of extraction, which would of course lead to false results.

The organic solvents removed large quantities of chlorophyll, fats, oils and waxes from the plant material, and these had to be removed from the extracts by chromatography on activated gypsum columns. The resulting solutions had then to be further purified by partition between various organic solvents, and by further careful chromatography. The solution at each step in these procedures were tested by bio-assay to determine where the active fractions lay. One point to emerge from this work was the fact that the new hormone was more active than 3-indolylacetic acid, the only hormone then known for certain to occur in plant tissues.

Small-scale extractions of one or two cabbages yielded enough of the new hormone to show by ultra-violet spectroscopy that it was an indole compound. Finally, a large-scale extraction of 500 kilograms of cabbage was carried out, and yielded almost a gram of semi-pure hormone, from which the hormone was isolated in crystalline form and chemically identified.

It turned out to be *3-indolylacetonitrile*, a rather unexpected result, since very few substances belonging to this class had previously been obtained from natural sources. This compound can be synthesised fairly easily. In fact it is an intermediate in the commercial production of

*This method, which is known as 'the straight-growth method', is described by one of the Manchester team, Dr. J. A. Bentley, in *Journal of Experimental Botany*, Vol. I, Pt. II, p. 201.

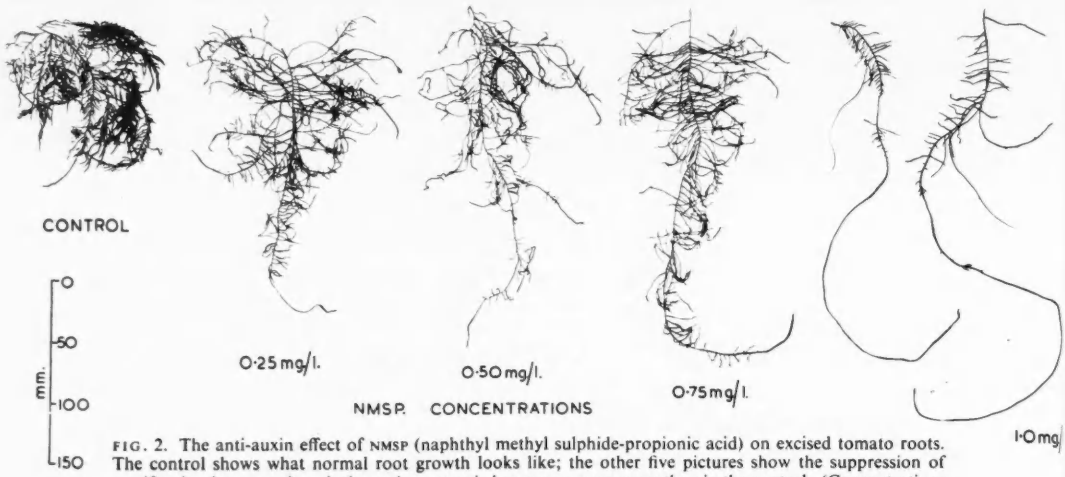


FIG. 2. The anti-auxin effect of NMSP (naphthyl methyl sulphide-propionic acid) on excised tomato roots. The control shows what normal root growth looks like; the other five pictures show the suppression of ramification by NMSP though the main root axis has grown even more than in the control. (Concentrations of NMSP are given in milligrams per litre.) (*Courtesy, the Editors of "Nature".*)

3-indolylacetic acid, and is therefore abundantly available for experiment. This allows studies to proceed on its role in plant metabolism and its place in the hormone picture. Work in this direction has already been carried out by the Manchester workers, who have investigated its effect on the various other aspects of plant development, in addition to cell-elongation, known to be affected by 3-indolylacetic acid.

They have found that the nitrile is less active than the acid in promoting the elongation of cells in pea stems (in sharp contrast to its greater activity in oats), in inhibition of root growth in cress, in inhibition of the development of lateral buds and the abscission of petioles, and in formation of new roots; but it is about as active as the acid in inhibition of root growth *in oats*, and in the initiation of cambial activity and the development of seedless fruits. Furthermore, it moves through tissues (at least through the tissues in oat coleoptiles) as easily, if not more easily, than the acid.

All these results raise questions as to the role of the nitrile in normal plant development. It has been established, by the technique of paper chromatography, that it occurs in a wide range of plant materials, and is not restricted to members of the Cruciferae family; other experiments suggest that it may cause *more normal* growth when applied to plants than does 3-indolylacetic acid.

Since the nitrile is a naturally occurring hormone, it is not to be expected that it would produce the dramatic effects on plants which the synthetic 'hormone' weed killers do. But just as the selective weed killers were modelled on 3-indolylacetic acid, so it is possible that synthetic compounds modelled on 3-indolylacetonitrile may show commercial possibilities in the control of plant growth. This is a field still to be explored.

Recent work on the chromatography of plant extracts has revealed the presence of further substances with hormonal or anti-hormonal properties (see *Nature*, 1953, Vol. 171, p. 645). Evidently, much remains to be done in this fruitful field of research.

* * * *

Since this note was written, *Nature* (1954, Vol. 173, p. 253) has published a paper in which Dr. H. E. Street, one of the Manchester team, produces evidence suggesting that a hormone other than indolylacetic acid (IAA) or indolylacetonitrile (IAN) influences the activity of excised roots growing in culture solution. He has been investigating the response of such roots to α-naphthyl methyl sulphide-propionic acid, an anti-auxin (i.e. a substance which acts counter to a plant hormone).

This compound is known to counteract the inhibiting effect upon root growth exerted by such hormones as NAA, 2, 4-D and IAA. Dr. Street finds that the presence of this organic sulphide radically alters the way his excised roots grow. In the ordinary culture solution which he uses in his experiments the detached roots thrive exceedingly and they ramify just as they would if attached to the plant. The anti-auxin completely upsets the ramification (see Fig. 2), and this is presumably due to its interference with some growth hormone which controls the development of new lateral roots. Dr. Street has considered the possible antagonism of the anti-auxin to both IAA and IAN, and comes to the conclusion that this cannot explain the results he has obtained. It looks as though he is on the track of a new plant hormone connected with the regulation of root growth.

REFERENCES

Jones, E. R. H., Henbest, H. B., Smith, G. F. & Bentley, J. A. (1952). "3-Indolylacetonitrile: a naturally-occurring plant growth hormone". *Nature*, **169**, 485.

Bentley, J. A. & Housley, S. (1952). "Studies on Plant Growth Hormones, I. Biological properties of 3-Indolylacetaldehyde and 3-Indolylacetonitrile", *Journal of Experimental Botany*, **3**, 393.

Bentley, J. A. & Bickle, A. S. (1952). "Studies on Plant Growth Hormones, II. Further biological properties of 3-Indolylacetonitrile". *Journal of Experimental Botany*, **3**, 406.

BICENTENARY OF THE ROYAL SOCIETY OF ARTS

This month the Royal Society of Arts celebrates its bicentenary, an anniversary of considerable interest since this society has a fine record in respect of its encouragement of scientific and technical developments. This activity has always been a prominent feature of the society's work, though to the outsider this may seem rather odd considering the society's title which, however, is a contraction for

the Royal Society for the Encouragement of Arts, Manufactures and Commerce.

Many societies with similar names exist in different parts of the world, and these are, of course, offshoots of London's R.S.A., which was founded on March 22, 1754. Throughout its long and distinguished history the society has fostered invention and technical innovation in all the many fields which have come within its purview. This it has done by rewarding inventors, a practice which was started in 1756 and which gave rise to annual prizes for worth-while inventions. For example, in 1780 we find the R.S.A. offering a gold medal for a steam engine for "working at one time the greatest number of looms, not fewer than three". This system of prizes certainly served to bring out the inventive capacity of craftsmen and artisans. An early award, for example, went to Abraham Staghold, a blacksmith of Maldon, for his screw jack; Staghold was awarded in the same year a grant of twenty guineas for his invention of the harpoon gun which was to revolutionise the whale-fishing industry. Civil engineering was considered to be within the society's scope, and one of the early recipients of its gold medal was Abraham Darby, the award being given for his famous bridge across the Severn near Coalbrookdale, which was the first iron bridge in the whole world. The naval architect, Sir Robert Seppings, who revolutionised the art of shipbuilding by the extended use of iron framing, was another early gold medallist.

The society cast its net very wide, and not unnaturally it sometimes tackled problems which were to prove a great deal more difficult than was originally anticipated. One such scheme which turned out a failure was the attempt to start a silk industry in Britain. A prize was offered in 1768 for English-raised silk, and repeated efforts were made to encourage the planting of mulberry trees (whose leaves are an excellent food for silkworms) and the raising of silkworms. The results were disappointing, and although perfectly good silk can be produced in Britain, production of this commodity in really substantial quantities has never proved profitable. There is consolation, however, in the fact that mulberry trees have become far more widespread in England than would otherwise have been the case!

A strong thread of practical philanthropy was early woven into the fabric of the society's activities, and it did pioneering work in the field now known as 'Industrial Hygiene'. New industrial processes were introducing new industrial hazards, and the society can take particular pride for its efforts to eliminate or minimise such hazards. A very early example from the society's records involved mercury, a metal which still presents industrial problems today. The water-gilding technique was then widely used, in which an amalgam of gold and mercury was applied to a metallic surface; the mercury was then volatilised off by heating, leaving a thin adherent film of gold behind. The process gave perfect results, but workmen suffered badly from the mercurial vapours. The society offered a prize for a method of reducing this hazard, and this was rapidly forthcoming, the fume chamber which solved the problem being the invention of a man named J. Hills, who kept a curiosity shop in Berwick Street. One cannot but admire the society's good sense in having this fume chamber tested by "Mr. Platts, a workman in the water-gilding way", who afterwards reported that "I wish I had been so happy as to have had the use of such an invention twenty years ago; I make no doubt but that I should have been free from the disorder I have so long laboured under". Some years later the society awarded a prize for an industrial respirator which further reduced the danger from noxious vapours encountered in gilding metals.

The toxic effects of arsenic also came to exercise the society's interest, and in 1821 it offered a gold medal for a test for arsenic. Not until 1836 was the medal awarded—the prizewinning test was the now classic 'Marsh test', produced by James Marsh, the Woolwich Arsenal chemist.

Quite a few scientific and engineering instruments were brought into being by R.S.A. awards, for example the tachometer of Bryan Donkin. The first electromagnet, invented by W. Sturgeon, won a prize in 1825. The popularity of the microscope, which became a parlour toy in the Victorian age, was largely due to the enterprise of the R.S.A., which in 1854 offered two medals—one for a simple microscope and one for a compound microscope to be sold at half a guinea and three guineas respectively. Messrs. Field of Birmingham won both prizes. According to Dr. W. B. Carpenter, sales of the second prizewinning microscope amounted to 1800 by the end of 1861.

The half-guinea microscope was paralleled by the shilling box of paints which won an R.S.A. medal in 1852 and was subsequently sold to the tune of eleven million boxes in less than twenty years!

The R.S.A. contributed a great deal towards the technical improvement of British farming during the first century of its existence. Arthur Young* was a keen member of the society, and chairman of its agricultural committee for many years; he himself was anxious to see the society establish an experimental station similar to the one started by the R.S.A.'s sister society in Dublin. This idea, however, never materialised, simply for lack of a suitable person to direct the experiments; otherwise the R.S.A. might well have anticipated the setting up of Rothamsted by a good many years. The society is entitled to the credit for sponsoring the introduction of the swede and the mangel-wurzel into England in 1767.

Many inventors of new agricultural machines benefited from R.S.A. awards, and the society did much to awaken public interest in Tull's drill (invented in 1707). A gold medal was given in the 1760's for Sir Digby Legard's experiments which extended over six years and established the advantages of seed drilling over broadcast sowing, and the Rev. Lowther of Cumberland was rewarded for a similar and conclusive set of experiments. John Common of Northumberland, an inventor much favoured by the society, invented a reaping machine which pre-dated the classic machine of McCormick; indeed it has been stated that "there seems no doubt whatever that Common's reaper was the original of the machine brought out by McCormick, and exhibited by him in the American section of the 1851 Exhibition as his own".

The Royal Society of Arts took the lead in starting the famous 1851 Exhibition, and it should be recalled that Prince Albert was the society's president at that time,

* Young received an R.S.A. gold medal for his potato work; and two prizes for growing madder.

occupying this position from 1843 until his death in 1861. The highest award of the R.S.A. is named after him, and many scientists have been honoured by the award of the Albert Medal, the last recipient being Dr. E. D. Adrian, present president of the Royal Society and the British Association.

THE A.S.A. LEARNS FROM ITS MISTAKES

The Atomic Scientists' Association has not always faced up to its responsibilities towards the public, a serious fault in a body which aims "to bring before the public of this country the true facts about Atomic Energy and its implications". It is, however, evidently making a considerable effort to rectify its shortcomings, and it certainly deserves a measure of praise for the course of London University extension lectures which it organised recently.*

One score on which the A.S.A. has been criticised has been its tendency to presume to speak on matters of great public importance as though it possessed some omniscient and special authority when in fact it was no better qualified to lay down the law than any other interested section of the community, or indeed any interested and well-informed individual person. We are pleased to find that the A.S.A. has taken note of this criticism, which was expressed by several members of the A.S.A. as well as by external critics. The association's journal has undoubtedly improved as a result. Thus in the January 1954 issue we find an article dealing with the American controversy over the strategic use of atomic weapons, a controversy in which certain scientists found themselves at loggerheads with the high-level policy makers. This article ends by raising the question "of the propriety of scientists trying to settle such grave national issues alone, inasmuch as they bear no responsibility for the successful execution of war plans". This is a most important issue, for there can be no doubt that the strategic considerations of modern scientific warfare are far too big and far too serious to be settled by scientists alone. There was a time when the A.S.A. journal would not have published an article voicing that kind of opinion, which some A.S.A. members may regard as unflattering even though it expresses no more than a self-evident truth. The appearance of that article is a welcome sign that the editorial policy of the A.S.A. journal has changed, and changed for the better. The political bias which used to spoil the magazine is disappearing, and it is now evident that attention has been given to the ethical considerations which arise whenever an organisation like the A.S.A. starts a journal that aims at influencing public opinion.

LESSONS FROM AMERICA

The British Commonwealth Scientific Office in Washington has produced its sixth annual review of scientific developments in the U.S.A. and this has been published under the title of *Science in U.S.A.* (H.M.S.O. 1954, 2*s*.). One point which emerges is the rapidity with which the Americans rise to any critical occasion. The western world was recently subject to an acute sulphur shortage, as our readers will all be aware. This affected most of the western nations, but the U.S.A. has done more than any other country to prevent a repetition of a shortage in sulphur. The manufacture of superphosphate represents a considerable drain on sulphur supplies, and in this connexion the U.S.A. has done well to develop the nitric acidulation of phosphate rock. Large plants working this process are being built by at least three large U.S. companies. New forms of phosphatic fertilisers are being developed by the Tennessee Valley Authority, which was largely responsible for perfecting the process of making triple superphosphate. (That process involves the use of phosphoric acid instead of sulphuric, and is a most valuable method of conserving sulphur wherever the phosphoric acid can be prepared electrolytically.)

One item in this report deserves special notice. Before the war many scientists considered that Britain had to import too much research equipment from abroad. Probably Britain can never be completely self-sufficient in this respect, but it is somewhat disturbing to realise the scale on which we are importing scientific apparatus and special engineering equipment from the U.S.A. According to *Science in U.S.A.*, $1,150,000 had been allocated by mid-1953 for the purchase of some 200 items of research equipment required by D.S.I.R. laboratories and industrial research associations. It is intended to procure a further sixty items under the same arrangements. Admittedly Marshall Aid has encouraged not only Britain but most of western Europe to rely heavily on America for such equipment, but we know of cases where orders for comparatively simple equipment are going to the U.S.A. in default of a little extra effort by British manufacturers to meet the requirements of our scientists. The tools of research represent a key industry which deserves and enjoys special encouragement by our Government and by the scientific community in this country. Wherever possible, Britain should be made self-sufficient in respect of these research tools. Certain branches of the industry have done their utmost to achieve this objective. It is up to the laggards to follow their example.

SCIENCE MASTERS

Our disclosure, in the January issue, that the money is already available for local education authorities to pay special rates for science teachers where this is necessary in order to fill vacancies came as a shock to many readers, and it certainly attracted the attention of the F.B.I. conference which was called to discuss the shortage of science teachers. It seemed as extraordinary to many industrialists as it does to us that the money is there but is not being spent. The available but unspent sum is not a small and inadequate amount; it is about £700,000, and there is no doubt that it could work wonders if it was spent to the best advantage.

The reluctance of L.E.A.s to spend this money is creating something of an impasse, which might be broken quite swiftly if industrialists were to put pressure on the L.E.A.s. The Minister of Education does not intend to apply pressure, and indeed Ministry pressure would probably do no good at all so far as this particular issue is concerned.

* These lectures are to be published in the April issue of the *Atomic Scientists' Journal*, which costs 4*s*. 9*d*. post free; there will also be a cloth-bound edition at 6*s*. 9*d*. (Any inquiries should be addressed to the A.S.A. at 15 Bloomsbury Square, London, W.C.1.)

Answering a question in the House of Commons on January 21 the Minister replied to criticisms that the new Burnham scales do not provide adequately for teachers engaged in the most responsible work, especially in grammar schools. She said that the critics "have not taken sufficient account of the provisions open to authorities for granting special allowances for the holders of particular posts".

The Minister said that the Burnham committee, in submitting the new scales to her, made special mention of these allowances in connexion with science and mathematics teaching, and she added "I have told the chairman that in deciding to approve the revised scales I have assumed that authorities will be ready to make ample use of the provisions for allowances in addition to scale salaries whenever this is appropriate."

M.P.s, we are glad to find, are now taking an active interest in this problem of getting a sufficiency of science teachers of the right calibre into the schools. More than one M.P. who has raised the problem in the House has used DISCOVERY's leaders on this topic to good advantage. The seriousness of the situation is now realised by many parliamentarians, and the need to treat it as a national problem is fully recognised. It is emphatically not a problem that can be solved by the Ministry of Education and the local education authorities alone, as Sir Philip Morris has said. One M.P. has extrapolated from this point and has gone so far as to suggest that the basic questions involved in this issue lie outside the purview of the Education Ministry. He was referring specifically to questions connected with the distribution among the different national users of scientists and mathematicians, which he described as "a very scarce national asset", and he asked, "Would it not be more appropriate, and in keeping with the Council's recommendations, that the problem should be taken out of the hands of one Department and put in the hands of, say, the Chancellor of the Exchequer, who has far more oversight than the right hon. Lady has at the moment over the basic questions involved?" (For those who are interested, the M.P. who asked this question was Malcolm MacPherson, M.P. for Yeovil.)

Personally we believe that little good will come from a diversion of attention and effort from the most urgent problem, *which is to secure an adequate supply of well-qualified science teachers to the schools*. One can, without any effort of the imagination, visualise the setting up of a committee to organise the rationing of new science graduates and their allocation into the different scientific professions, but after carefully considering the results achieved by the Barlow Committee is it possible to believe that such a step would bring any real benefit? The Barlow Committee, which reported in 1946, was concerned with securing a balance between the supply and demand for science graduates. Their target was a doubling of the output of new science graduates by 1955. The universities have doubled their output as the committee recommended, but in the intervening period the fabric of school science teaching has suffered inestimably serious damage. It was obvious in 1946 that it would be essential to recruit more science graduates in order to reinforce the ranks of the science masters, for upon the science masters rested the initial responsibility for getting more pupils interested in scientific careers and for starting them on the road to a science degree. In raising this matter, we are not being wise after the event; if readers will look back to our leader (July 1946) on the Barlow Committee's report they will see that we called then for some adjustment of salary scales for science masters and referred to "the vital necessity of securing a fair proportion of science graduates for teaching", adding the comment that "these salaries are such as to discourage a prospective teacher from undertaking a university course in science. . . . The lead of salaries is going to determine not merely whether the best use can be made of the scientists who are already trained; it will also affect the number of students who will choose science as a career." In the post-war years the shortage of science masters has become steadily more serious, and today it represents a real bottleneck in the training of scientific personnel—a development which we predicted as long ago as *January 1946*. It seems to us that the Barlow Committee was in a position to exercise just that broad oversight which Malcolm MacPherson wants some department such as the Treasury to exercise. Might it not be more profitable to suggest that all government departments and other bodies concerned should meet their own particular individual responsibilities connected with this problem and take the promptest possible action to put things right. For instance, special responsibility allowances are at present paid to only a fraction of sixth-form science masters—the figure is probably well below 50%. At present it is left to local education authorities to decide how many of the science masters under their control shall receive these S.R. allowances, with the result that in an individual school one finds that two of the science masters get this extra payment and that the other two do not—even though all four are doing very much the same work. It is obviously unfair if, say, the mathematics master and the physics master get an extra £100 a year, whereas the chemistry and biology masters who have to teach their subjects at the same level (and probably to the same boys!) get nothing. At this point it may be necessary for the Education Ministry to step in and put an end to such anomalies. Perhaps it will become necessary for the Ministry to decide that all sixth-form science teachers in maintained schools shall receive a special responsibility allowance, and presumably, to make the arrangement equitable and fair, this allowance would also have to be paid to the sixth-form masters teaching subjects other than science. This decision could only come from the Education Ministry. We have not been able to figure out how much it would cost the country, but certainly the unspent £700,000 would go a long way towards paying the bill. Undoubtedly many L.E.A.s would not be pleased if the Ministry was to come to this decision, for then the payment of S.R. allowances would cease to be largesse which L.E.A.s can dispense as they see fit. But in view of the fact that the L.E.A.s have allowed the serious shortage of science masters to develop, and in view also of the fact that they are doing very little to rectify the shortage and seem very reluctant to use any of the unspent £700,000 mentioned above in order to improve science teaching in schools, could they reasonably complain if the Education Minister took this decision?

On March 14

EINSTEIN IS SEVENTY-FIVE

by

DR. J. BRONOWSKI

In 1954 we look ahead into a world of which we can be sure of little except that, under the influence chiefly of modern science, it will continue to change rapidly. And our thoughts may well turn to Princeton in New Jersey where, on the eve of his seventy-fifth birthday, surrounded by books and German *Gemütlichkeit*, lives the man who has done more than anyone in this century to change the perspective of science itself.

* * * *

Albert Einstein has remade the outlook of all who live with or after him, as Newton once did, and as Darwin did. There are, of course, people who still think of science only as a heap of gadgets, and grumble at the growing complexity of the tin-opener and the atomic pile. But the penetration of our lives by the discoveries of the great scientific minds has been deeper and more radical than this. And it is not the complexity but the simplicity of their thought which has made it a challenge to all that others took for granted. Newton, Darwin and now Einstein were not in any sense brilliant thinkers, quick at academic research or crackling with fireworks of invention. All three were fairly slow boys at school and college. All three made their discoveries away from the seats of learning, alone. All three brought to the study of nature the searching simplicity which hermits once turned on their visions.

* * * *

Einstein was born in a Jewish family in Germany on March 14, 1879. His father did not prosper in business, and moved first to Switzerland and then to Italy in search of better luck. When the boy was left behind at school in Germany, he ran away. Later he finished his degree course with difficulty in Switzerland. He had no university prospects, and had to take a job as a minor official in the Swiss Patent Office. He did his own thinking in the evenings, and he was still working in the Swiss Patent Office when he published his first great papers in 1905.

In these, in one year, the young man of twenty-six made outstanding advances in three separate branches of physics. To most people now, Einstein's name stands simply for Relativity. And certainly the most adventurous of the papers of 1905 was the first statement of the theory of Special Relativity. But the theory of Relativity would have been read with less attention if Einstein's other work from 1905 had not marked him equally as a leader in framing the concepts of the new quantum physics. All his work in this *annus mirabilis*, his wonderful year, has the same stamp of simple intellectual grandeur: it looks into the heart of physics.

The heart of physics at that time had developed a murmur, which was small but nagging. The triumphant laws in which Newton had given order to nature for more than 200 years could still be tested and found right, almost everywhere. But only *almost* everywhere: elsewhere, there was the small murmur of exceptions. The planet Mercury was not keeping time; the speed of light refused to behave as classical physics expected; and the newly discovered electrons seemed to change their mass with their speed.

Physicists were trying to meet these minor irregularities with minor adjustments. Einstein from the outset looked for no ingenious gloss on the laws of physics and for no small errors of formulation. He looked at the unwritten assumptions on which the laws had been built, deliberately, by Newton.

* * * *

Put in scientific terms, the assumptions were that space and time are given to us absolutely and are the same for every observer. Put more generally, the assumptions postulated a sharp division between the observer and the natural world. Classical physics saw nature as a chain or network of events which unrolls itself in imperturbable sequence, and of which the observer is a witness but not a link. The observer is a god, altogether outside the machine of the physical world.

What Einstein asked about this majestic view was not whether it is *true*, in some abstract sense, but whether it is *practical*. Does science in fact record impersonal events? Can it distil the actual event from our observation of it? Once the question is asked, the answer is plainly, No. Physics as we practise it does not consist of events; it consists of observations. And between the event and those who observe it there must pass a signal—a ray of light perhaps, a wave or an impulse—which simply cannot be

taken out of the observation. Event, signal and observation: that is the relationship which Einstein saw as the fundamental unit in physics. Relativity is the understanding of the world not as events but as relations.

* * * *

Something like this had been said by philosophers for some time: that science must get rid of abstractions, and make its system only out of what is in fact observed. Einstein himself acknowledges his intellectual debt to philosophers of science—Ernst Mach in Vienna, Henri Poincaré in Paris, and the first and greatest sceptic about our habits of thought in and outside science, the 18th-century British philosopher David Hume. But it is a long cry from laying down the law how science should or should not be practised, and in fact persuading the man at the bench or the man with a slide-rule.

Einstein put this practical view into his equations; and in time physicists were astonished to find that it explained the erratic behaviour of Mercury and predicted the bending of light. His first papers established a link between energy and mass.

* * * *

I want to underline the content of these ideas, because it goes beyond physics. This is a view of science, and indeed of all knowledge, not as a mechanical record, but as an activity. Einstein had not asked himself what space and time are, metaphysically; he had asked how physical observers carry out the process of measuring them. For example, how do two observers at a distance apart compare their times? They can do so only by sending a signal from one to the other, and the signal itself takes time to travel through the space between them. It follows that there is no way in which we can define 'now' for all observers, everywhere at once. Every observer has only his own 'here and now'. In our experience of nature, space and time cannot be wholly separated from one another; each is part of a single reality. And this is not an abstract conception like Euclid's space. Einstein's space-time is a real medium in which physical processes act and are observed. It is given its structure by the matter which it contains, and this matter bends and closes it because the function of space and time is precisely to enclose matter.

These are the deep and challenging ideas with which Einstein revolutionised both large-scale and quantum physics. He enlarged them to include gravitation in the theory of General Relativity in 1915, and is today still working on a Unified Field theory which should extend them to electricity and magnetism. And it will now be plain why the influence of his ideas has been so much wider than science. For they are universal ideas; they reach below mathematics and physics, to the basic conception of the relationship between man and nature.

* * * *

The question which Einstein asked in the theory of General Relativity in 1915 is of the same kind. Whatever physicists may hold, we do not in fact talk about the mass of a body; and indeed Newton had difficulty in framing a definition of mass, and failed. We talk about the weight of a body. Why are mass and weight always related? When I throw a ball, I overcome its mass; when I lift it, I overcome its weight. Why do I experience them as the same?

For answer, Einstein gave a new picture of the field of gravity round a body. A massive body, he said, distorts the space-time in which it lies; it forms, as it were, a hollow round itself. When I drop a ball and it falls, it is really rolling like a marble into the hollow made by the earth. This is the nature of its gravity or weight. And the earth itself is like a larger marble which flies round the hollow in space-time made by the sun.

This is an attractive picture which can be seized at once. If it is a true picture, and describes an actual distortion of space and time, then everything which crosses the sun's hollow must be drawn inwards: not only a ball which has mass, but a ray of light as well. This unexpected prediction, in the middle of a world war, made astronomers fit out two expeditions to watch the next eclipse of the sun. But it will be well to pause here for a moment and recall the war.

* * * *

When the first war broke out in 1914, Einstein had been a young giant and an *enfant terrible* among physicists for some years, and was director of the Kaiser Wilhelm Research Institute for Physics in Berlin. The German Government was anxious to find intellectual support for its imperial ambitions, and put great pressure on its leading men. Ninety-three of them signed a manifesto of support. Einstein did not sign, and with two others issued a counter-manifesto against militarism. Einstein had in fact chosen

Einstein, from the sketch book of Joss of the *Star*.

The atomic bomb aroused public awareness of Einstein's equation $E=mc^2$. It was Einstein's letter of August 2, 1939, which drew President Roosevelt's attention to the military possibilities of nuclear fission. (*Eniwetok Test, 1948*; *U.S. A.E.C. picture*)

Swiss nationality as a young man because he disliked German regimentation; and he chose later to become German again as a gesture of support to the Weimar Republic.

* * * *

The Weimar Republic exposed him to attack on two flanks. To the rising Nazis, he and his theories were of course simply un-German. To men across the Rhine with bitter memories, he was a German scientist of whom too much fuss was made. In 1919, the eclipse expeditions had confirmed to the world what no one had guessed before General Relativity, that light bends towards the sun. In 1921 Einstein was given the Nobel Prize—cautiously, not for Relativity. When Einstein visited Paris in 1922 to lecture, he was hidden from French nationalists who might demonstrate against the German. Twenty years later the demonstrators were collaborating with the Nazis, and Einstein had fled from both. Those who hid him in 1922 recall with pleasure that he brought his violin and played in quartets.

Einstein went to America in 1932 and has worked at the Institute for Advanced Study in Princeton since. He had been a lifelong pacifist. Yet he broke with this as with other doctrines when it no longer fitted the facts of the world. On August 2, 1939, he wrote to tell President Roosevelt that recent work in atomic physics, which had been disclosed to him privately, made it probable that an atomic bomb could be constructed; and that, since this work had been begun in Germany, the Germans might make such a bomb. The marvellous youth who at twenty-six had for the first time equated mass with energy, now at sixty saw that equation threaten the world.

* * * *

I ought not to close this account of Einstein's scientific work without drawing attention to one respect in which his recent theories differ from those of other physicists. Physicists who have spent their lives working with quanta have for the last twenty-five years abandoned the hope of making a model of the small-scale world in which every effect shall have a cause. Instead, they have accepted a principle of uncertainty which says that there is an essential limit to the possible prediction of minute events; and that we can never know which of two alternative paths one of the tiny units of nature, an electron, a light quantum, or part of a nucleus, will take—or has taken. Einstein is almost the only great physicist who has steadfastly opposed this view. The theories by which he has recently proposed to unify all the physical forces (electro-magnetic as well as gravitational) are field theories, which are strictly causal.

It can be shown that these causal-field theories lead to contradictions when they are applied to very small units of matter, if these units are arbitrary. But this does not deter Einstein. He believes that the contradictions must resolve themselves, because the units to which they can be applied must somehow arise out of, and be fixed by, the equations themselves.

That is, if Einstein's new Unified Field equations are to be true, then they must contain within themselves conditions which make them applicable only to the precise sizes in which matter actually occurs. The fundamental units of nature have not been fixed arbitrarily, says Einstein—on no logical ground, but simply because he does not believe that 'God played at dice'. And at seventy-five, he is still cheerfully ready to trace the exact shaping hand of God.

* * * *

He lives quietly in a suburban house in Princeton. Not long ago he refused the Presidency of Israel because he thought himself too old. He is patient even with the strangers who sneak up to his front porch and have their wives photograph them as if they were just coming out of the great man's house. If he has any impatience left it is, as it always was, with authority. Recently an English scientist visiting Washington had occasion to telephone Einstein's house. He could hear the long-distance operator say to his housekeeper, "Washington is on the line for you." And he heard the housekeeper exclaim, in horrified German "*Herrgott*! Washington! What is wrong now?"

(*This article is published by arrangement with the "Observer".*)

THE NATIONAL INSTITUTE OF OCEANOGRAPHY

CHAPMAN PINCHER

Though Britain's strength both in trade and defence has so long depended on command of the seas, no comprehensive research centre for the study of the ocean existed in the country until quite recently. Marine biology has long been well catered for at Plymouth and Millport, in the Fishery laboratories at Lowestoft and Aberdeen, and in several university laboratories, but except for the tidal research carried out at the Liverpool Tidal Institute, Britain was backward in studying the physics of the sea.

Four years ago it was decided to set up a National Institute of Oceanography, under the leadership of Dr. G. E. R. Deacon, F.R.S. with the object of "advancing oceanography in all its aspects". Research projects already in hand at the Admiralty Research laboratory, the Discovery Investigations and the Wave Recording station at Perranporth were taken over. New ones were begun. These projects involved—as they always will—frequent trips by the scientists on the high seas. Valuable results were obtained, but the fact that the Institute lacked any permanent and centralised home held up the rate of progress at which knowledge could be advanced.

A few months ago, however, the Admiralty was able to hand over a first-rate headquarters for the Institute in the form of a big brick building put up near Witley in Surrey for signals research during the war.

Conversion of the building to the laboratories, workshops and offices needed for the varied programme of research planned by Dr. Deacon and his staff of about 30 scientists is almost complete and there is already much scientific work going on there.

Siting a headquarters for oceanography on a dry hill in Surrey may seem odd, but nearness to London and the universities were considered to be more important than nearness to the coast. Most of the Institute's work will be done in the deep sea, and London's rail termini give quick access to all parts of the coast-line

The *physics* of the ocean—its movements and its fluctuations in temperature and density—dominate the work of the Institute. Typical of this side of the research is the ingenious analysis of waves, the ultimate object of which is to allow the wave conditions at any place to be predicted from wind charts and a knowledge of the local hydrography.

It has been found that when the wind whips up the sea it passes on its energy to a whole range of wavelengths. When the wind is light most of its energy goes into short waves. With increasing duration of the wind its energy is concentrated more and more in the longer waves, a common distance between consecutive wave crests in the Atlantic being 160–320 feet.

The waves of different length travel across the ocean at different speeds, the long ones moving very fast, speeds up to 60 knots being common.

These long waves, which may not be high enough to be visible, can be detected by shore-based instruments. So they provide a reliable method of detecting the occurrence of a storm far out at sea up to 12 hours before the swell caused by the storm arrives off-shore. Such detecting instruments could be of great value off certain islands, such as Mauritius, by warning the fishermen of a possibly dangerous swell.

A most ingenious method of studying wind currents undertaken with the help of the Post Office, by using a spare undersea cable has been devised by Mr. K. F. Bowden, one of the Institute's physicists.

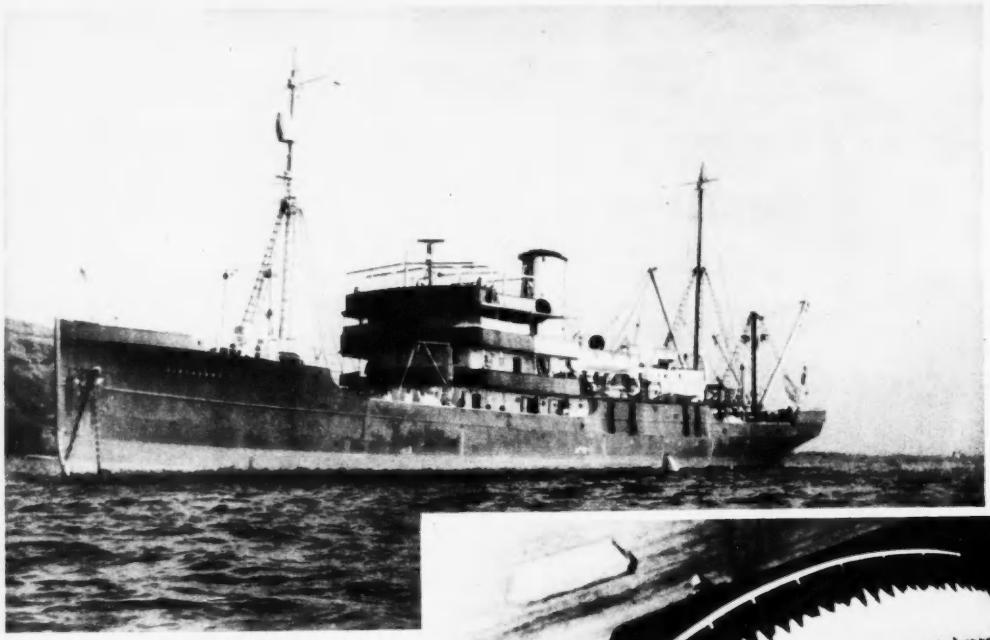
The water flowing backwards and forwards along the Channel is moving through the earth's magnetic field. This action produces a small fluctuating voltage in the cable which can easily be recorded as a wavy line on a roll of paper. That part of the record due to the tides can be deduced. The remaining fluctuations are due to drift currents produced by surface wind action.

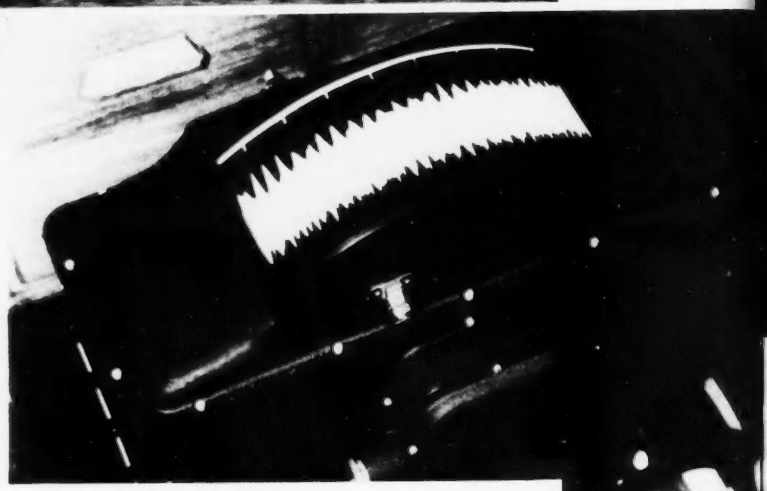
The ability to devise novel instruments is an outstanding feature of the Institute's staff. Current meters, which make continuous recordings of the strength and direction of underwater currents, wave-analysers, a roller which trundles over the sea-bed measuring its profile, and recently a device to measure the height of waves in the open sea have been built.

A pressure-meter in the shipborne wave-height recorder —designed by Mr. J. Tucker and Mr. F. E. Pierce— measures the height of waves above a small hole in the ship's side while the displacement of this hole due to the up and down movement of the ship is recorded by a vertical accelerometer. Measurements made so far during voyages in the N.E. Atlantic ocean suggest that waves of a height of 40 feet are common in very bad weather.

The scientists find that they can even study ocean waves in The Old Deer Park at Richmond! When trains of waves of the same dominant period collide—as they sometimes do near the coast or far out at sea during storms—they cause a pressure change on the sea-bed. This generates a slight earth tremor which can be detected at great distances by a sensitive seismograph. The analysis of seismograph records made at Kew is used to obtain information about waves reaching the west coast of Britain and about storms up to 1500 miles away. As these seismic disturbances travel much faster than even the long waves mentioned above, they can sometimes be used to give very early warning of approaching storms. By quickly comparing seismograph recordings from stations 1000 miles apart—which could be done by mutually exchanged radio signals—it might be possible to locate the position of storms and plot their line of approach.

Dr. Deacon is investigating the speed at which the bulk of the Atlantic water moves from the American coast to our shores. A preliminary result suggests that it takes about two and a half years to cover the 3000-mile distance. This figure links up nicely with the fact that baby eels spawned





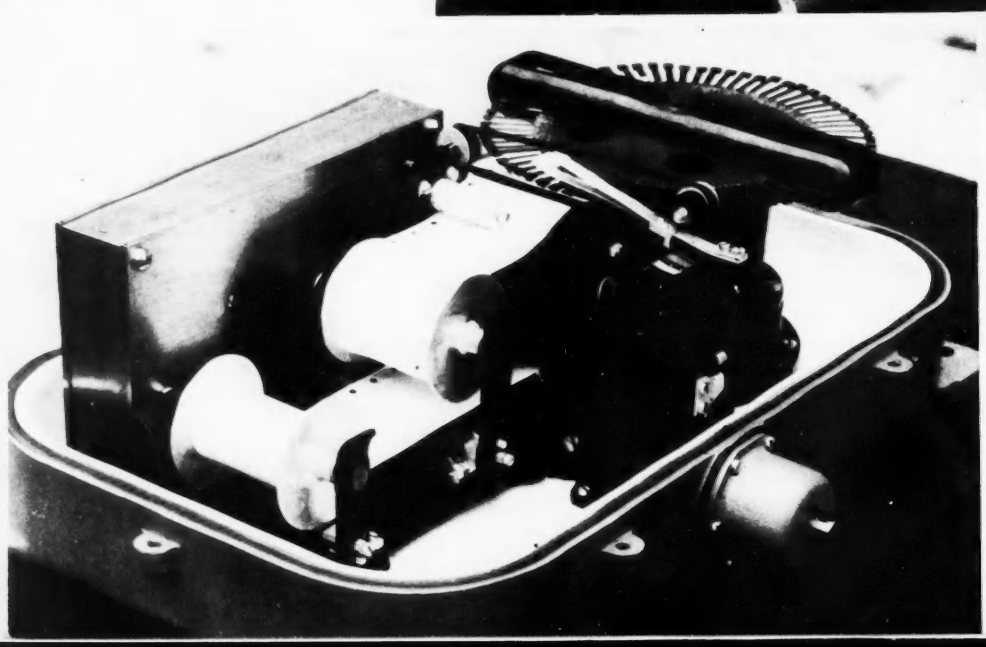
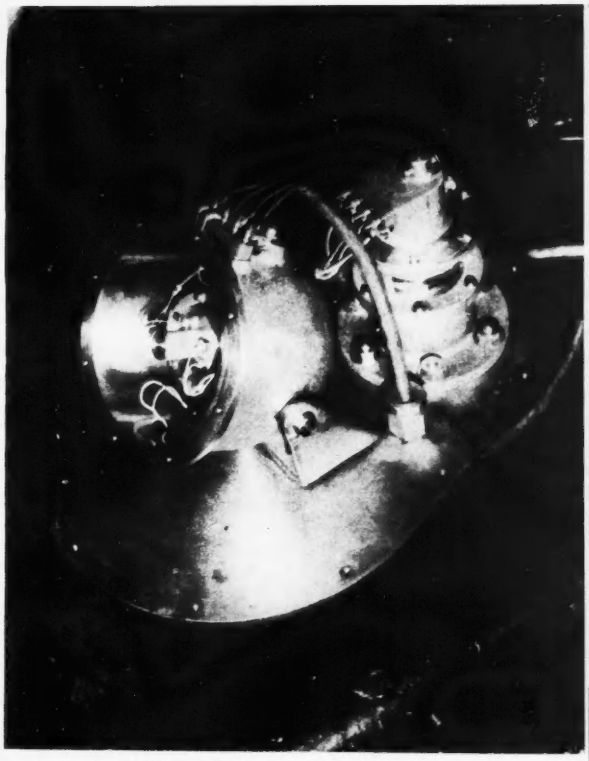


FIG. 1 (*top*). Royal Research Ship *Discovery II* in Plymouth Sound.
FIG. 2 (*right*). Wave analyser as fitted in R.R.S. *Discovery II*.
FIG. 3 (*bottom*). Recording box of current meter. The measuring cups (not shown in the photograph) operate the ratchet shown on the left and the hammer stamps the compass bearing on the clock-driven recorder paper every 50th revolution of the cups.



FIGS. 4 and 5. Ship-borne wave-recorder fitted in R.R.S. *Discovery II*. Fig. 5 (*right*) the wave-recorder opened to show the accelerometer above and pressure recorder below.

not far from the U.S. coast take two and a half years to reach British rivers. They are too feeble to swim the distance and are carried here by the currents.

Biologists of the Institute are carrying out work on deep-sea fishes—for example, they are trying to devise a fish trawl for sampling the more active animals which usually escape towed nets. An electric field will be created to guide the animals into the net or at least prevent them from escaping as the trawl approaches. Using a huge fish trap, they have tried—though not successfully—to capture coelacanth 'fossil' fishes off the African coast.

The main biological work of the Institute, however, concerns whales. To gain further information about the migration of whales, hundreds of them have been marked with a small, numbered, stainless-steel tube fired into the blubber from a 12-bore shotgun. This work was started by the Discovery Committee before the war and was taken over by the National Institute of Oceanography. The tubes are normally fired from the deck of the research vessel, but experiments have been made to test the feasibility of firing them from a helicopter.

More than 300 of these marks have been recovered. They show that blue and fin whales tend to revisit the same part of the Antarctic year after year after their winter migration to warmer tropical waters, while hump-back whales keep to their territory even more rigidly.

Some of the marks have been carried in whales for up to 18 years.

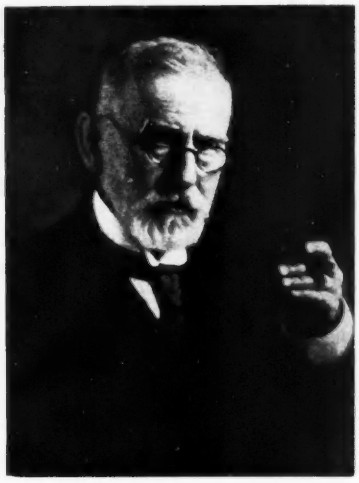
The Institute is also making a collection of whale ovaries, which bear evidence of former breeding periods and give information on the age distribution of the whales in the catch.

The distribution of 'krill', the small crustaceans on which some whales mainly feed, is also being mapped. The work has shown that krill are found mainly in waters inside the Antarctic circle. The eggs sink and hatch at a depth of 3000–4500 feet. There a bottom current carries the young larvae to less high latitudes, where they rise to the surface after passing through several stages of life history. The surface currents in which they spend most of their life have a northerly drift and the mechanism by which the stock of krill is maintained in the Antarctic waters is still somewhat uncertain.

The Institute possesses two already famous research vessels—the *Discovery II*, a 1000-ton steamship designed for deep-sea research—and the *William Scoresby*, a 324-tonner built for the study of whale migration. The *Discovery* has recently been equipped with underwater television equipment for study of the sea-bed. A camera designed for use down to 1000 feet relays a good-quality display to a TV screen mounted in the ship. Preliminary observations of the geology of the sea floor have been made in the Channel, round the Azores and on the Gettysburg Banks off the coast of Spain where the water is so clear that fish moving 150 feet away from the camera can be seen on the TV screen.

In addition to all this, the Institute does a certain amount of *ad hoc* defence research for the Admiralty—which contributes £50,000 a year to the Institute's expenses—but the great bulk of the work is freely published.

PAUL EHRLICH (1854-1915): FATHER OF CHEMOTHERAPY



by

H. O. J. COLLIER, Ph.D.

Chief pharmacologist, Allen & Hanburys Ltd., whose new book entitled *Chemotherapy of Infections* has just been published.

From time immemorial men have treated infectious diseases with drugs; but only in the present century have they called this 'chemotherapy'. To use the term implies that the treatment is scientific, perhaps even originated in a laboratory. We owe the word chemotherapy to Paul Ehrlich, who, in launching this science, obeyed his own rule, "Work upon what is *going to be* of great value, not upon what is already in existence."

Paul Ehrlich was born on March 14, 1854, the only son of a Jewish couple who kept an inn in the town of Strehlen in Upper Silesia. 'Ehrlich' means 'honest' in German, and love of truth was certainly among Paul's most obvious qualities. His honesty, his clarity of mind and his directness of expression were to lead him into conflict with many people who disagreed with his novel ideas, but he never lacked the capacity or the courage to defend himself against his opponents' attacks.

LESSONS FROM STAINS

By his own reckoning, Ehrlich first began working on chemotherapy when he was twenty-nine. That was in 1883, when he was medical assistant to von Frerichs, director of the Charité Hospital Medical Clinic in Berlin. Here Ehrlich busied himself with the great variety of new dyes that the German chemical manufacturers were synthesising. He used these dyes as selective strains for blood and other tissues prior to their microscopical examination, and in 1882 he had succeeded in finding a way to stain the tubercle bacillus in specimens of sputum so that doctors could easily recognise it. That discovery he made a few days after Robert Koch had announced his discovery of the agent of tuberculosis.

Ehrlich was interested in stains because he was interested in chemistry and wanted to apply chemical knowledge to medicine. The differential staining method gave him the idea that guided his future work, as this quotation proves:

> I have been led onward upon this path by the 'vital dyestuff injections' in which it is very easy to watch the distribution of the dyes both macroscopically and microscopically and in which, according to the constitution of the dye applied, very different localisations can be observed. Especially interesting in this connexion is methylene blue. This dye has a special relationship to the living nerve fibres . . . so that one can follow up . . . the dye into their very finest ramifications. . . . It is even possible . . . to stain the parasite which is sucking blood from the urinary bladder of the frog. . . . Anyone who has seen such pictures, with their wonderful display and distinctness will be immediately convinced of the necessity of regarding the distribution of such substances, within the finest elements, as the basis of pharmacological investigation.

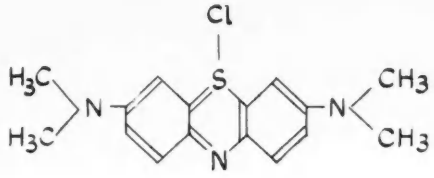
Using methylene blue, Ehrlich attempted a new experimental treatment. He was struck by the fact that it readily stained the malaria parasite, just as it selectively stained the nerves in the frog's bladder, and he therefore enlisted the support of Gutman to try out the dye against human malaria. In 1891 they reported that methylene blue made a detectable impression upon this pathogen, and exerted some curative effect. The dye was not potent enough, however, to replace quinine, but it was strong enough to confirm Ehrlich's faith in the truth of his idea.

SYNTHETIC ANTIMALARIALS

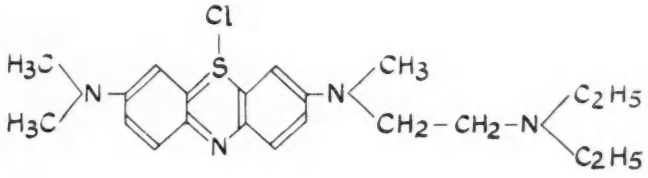
Ehrlich could not follow up this observation (which might perhaps have led him to find a new remedy for malaria), because he did not know of any malarial infection of laboratory animals on which to test further substances. It was over thirty years later, after World War I in fact, that Roehl adopted a malarial infection of birds for such experiments, a technique which enabled Schulemann and his colleagues to find that they could improve upon the antimalarial action of methylene blue by introducing a basic side-chain into the molecule. Following this up, they attached basic side-chains to methoxyquinoline, which is a prominent part of the quinine molecule. The resulting compounds showed powerful activity by Roehl's test, and one of them was selected for clinical trial in 1925. This was *pamaquin*, or *plasmoquine* as it was originally called (Fig. 7)—the first synthetic antimalarial.

Pamaquin is rather too toxic for the routine treatment of malarial attacks, but it has antimalarial properties not

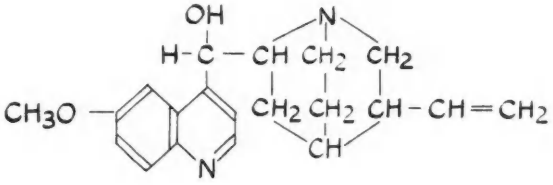
METHYLENE BLUE



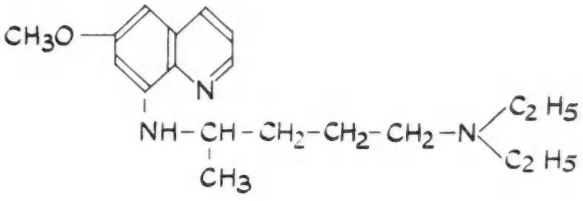
DERIVATIVE OF METHYLENE BLUE WITH BASIC SIDE-CHAIN



QUININE



PAMAQUIN



PRIMAQUINE

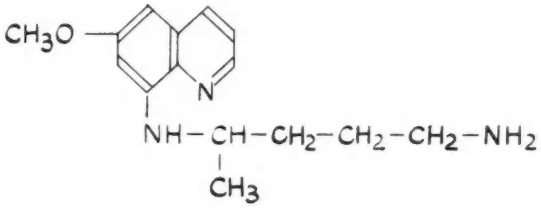


FIG. 2 THE CHEMICAL ANCESTRY OF PRIMAQUINE

possessed by more efficacious drugs, such as mepacrine (atebrin) and chloroquine. Pamaquin damages the tissue forms of the parasite that may remain in the body after an attack of malaria and cause relapses. For many years combined treatment with pamaquin and quinine was used to forestall relapses of benign tertian malaria, but this combination has now been superseded by primaquine. This drug, a close chemical relative of pamaquin, was synthesised in the United States during World War II, where facilities for testing antimalarials in the laboratory were sufficiently improved to enable a finer selection of compounds to be made. The sequence from Ehrlich's

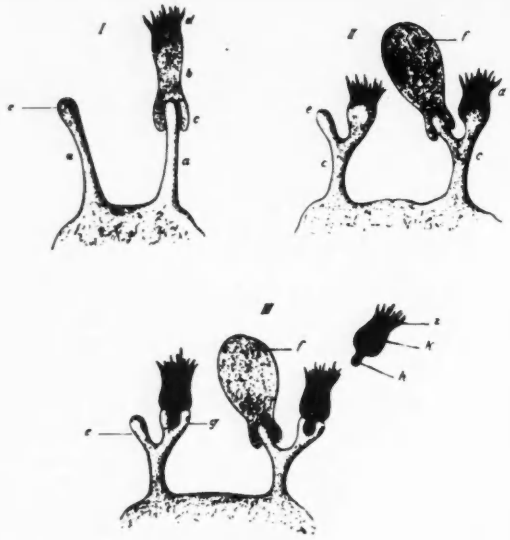


FIG. 3. Diagram of Ehrlich's 'Side-Chain Theory'.

I. Receptor of the first order. (c) haptophore complex; (b) adsorbed toxin molecule with (c) haptophore group; (d) toxophore group.

II. Receptor of second order with (c) haptophore group; (d) zymophore group and (f) adsorbed nutritive molecule.

III. Receptor of third order. (e) haptophore; (g) complementophile group; (k) complement with (h) haptophore; (z) zymotoxic group; (f) nutritive molecule.

study of methylene blue to primaquine is shown in Fig. 2, and it provides but one example of Ehrlich's talent for 'starting something'.

SERUM RESEARCH AND CONTROL

Both before and after this excursion into chemotherapy, Ehrlich devoted most of his time to immunology, constantly applying his researches to practical questions. It was he who showed how the natural protective substances (antibodies) which the body produces in response to infection could be prepared from animals in sufficient strength for clinical use. It was he also who, in Sir Henry Dale's words,* "devised accurate methods for measuring their curative potencies in terms of permanent standards, and defined units of activity in which these values could be expressed—in which, in fact, they are still expressed, all over the world. And, in doing this, Ehrlich had further established, once and for all, the scientific principles which are fundamental to the measurement and dosage of a large class of modern remedies."

These methods of measuring the biological activity of substances have been built into he science of biometry and provide essential tools in the d scovery and production of remedies for disease.

Ehrlich's work in immunology led him to attempt an explanation of the way antibodies work, for which he again drew inspiration from his observations on the distribution of dyes: "The protective substances . . . attack the bacteria only and not the tissue itself. These substances are exclusively 'parasitotropic' and not 'organotropic' and it is not surprising that they seek their object like a magic bullet." He gave a fuller explanation of the way these 'magic bullets' acted in his complex side-chain theory (see Fig. 3), which is well-known but not so well understood.

HOW DO DRUGS ACT?

The work of Ehrlich and his contemporary immunologists showed that antibodies were almost powerless to protect the body against certain diseases, such as African sleeping sickness, malaria and syphilis. He concluded that medical scientists should look instead for chemical treatments of these diseases. The opportunity to pursue this aim came to Ehrlich when he was forty-eight years old and had been for six years director of the State Institute for Serum Research and Control, which was first housed at Steglitz and afterwards at Frankfurt-a-M. The opportunity came with the discovery by Laveran and Mesnil, in 1902, of how to maintain in laboratory animals the trypanosomes that caused sleeping sickness. Ehrlich introduced trypanosome infections into his laboratory in Frankfurt and applied once again to their chemotherapy the principles of drug distribution. His guiding principle was this: "The whole of this field is dominated by a quite simple, I might even say independent principle. If for chemistry the law applies: *corpora non agunt nisi liquida* [chemicals do not react except in fluids], then: *corpora non agunt nisi fixata* [chemicals do not react unless fixed] is appropriate for chemotherapy."

The supposition that most drugs act when absorbed on to the surfaces of particles within living cells has been generally accepted. The particles largely concerned are the macromolecules of proteins, particularly those of enzymes, which are "the instruments of change in living cells" (Fildes). As Prof. Adrien Albert has pointed out, such surfaces in living organisms are large and likely to be reactive; to quote Albert's own words, "In an apparent solution like human serum, there are 100 square metres of protein surface in every cubic centimetre. . . . A surface presents a 100 per cent concentration of the substance involved. . . . As the substance is sparingly soluble . . . this concentration enormously increases the opportunities for the reaction taking place."

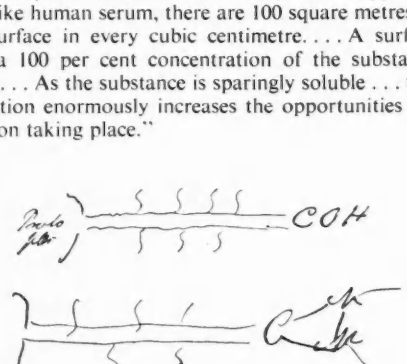


FIG. 4. Ehrlich's drawing of a chemo-receptor taking up a drug.

* Sir Henry Dale studied chemotherapy under Ehrlich at Frankfurt, immediately before joining the Wellcome Physiological Laboratories as a pharmacologist.

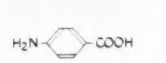
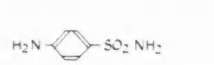
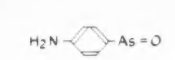
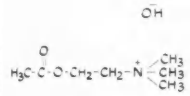
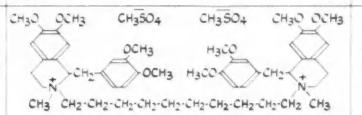
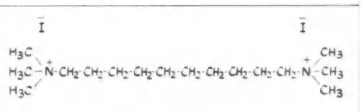
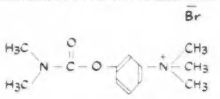
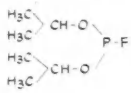
METABOLITE	SITE OF CHEMORECEPTORS	DRUG BLOCKING ACCESS OF METABOLITE TO CHEMORECEPTORS	DRUG ENTERING INTO REACTION AFTER ATTACHMENT TO CHEMORECEPTORS
 *p*-AMINOBENZOIC ACID	? ENZYME SYNTHESISING PTEROIC ACID	 SULPHANILAMIDE	?  PROBABLE ACTIVE PRODUCT OF ARSANILIC ACID IN THE BODY
 ACETYLCHOLINE	MOTOR END-PLATE OF MUSCLE	 LAUDEXIUM METHYLSULPHATE	 DECAMETHONIUM IODIDE
	CHOLINESTERASE	 NEOSTIGMINE BROMIDE	 DIISOPROPYLFLUOROPHOSPHONATE

FIG. 5. METABOLITES, METABOLITE-BLOCKING AGENTS AND REACTIVE DRUGS.

How does the drug get on to the surface? Ehrlich expressed the following view:

> We have made experiments with substances obtained by reducing Atoxyl (arsanilic acid) and derivatives of the phenylarsinic acid; and we have convinced ourselves that not only the arsenic becomes fixed to the protoplasm, but that the other groups of the chemical molecule are also fixed in the same manner by specific receptors. There must therefore . . . exist more receptors in the cells. The chemical substance is, so to speak, fixed, with its different groups in succession, by special catching claws or traps of the protoplasm.

Fig. 4 is a drawing by Ehrlich of one of these "catching claws of the protoplasm". It is a side-chain ending in an aldehyde group to which a drug molecule becomes attached by a diamino grouping. In these ways Ehrlich argued the existence of specific *chemo-receptors*—a concept that harmonises with the fact that a macromolecule in a body fluid is likely to have on its surface unsatisfied valencies, whose character and distribution will depend on its chemical nature.

METABOLITE-BLOCKING AGENTS

A chemical substance that takes part in the metabolism of a living organism may be called a 'metabolite'. In the processes of growth the cell's enzymes presumably take up, by means of chemo-receptors, the appropriate metabolites and cause them to react. It is now held that certain drugs act solely because they are taken up on to the chemo-receptors in place of some necessary metabolite, which they resemble in chemical structure. For example, Woods showed that sulphanilamide inhibits bacterial growth because it blocks access of *para*-aminobenzoic acid to an enzyme in the bacterial cell (Fig. 5). It is easy to see that such a blocking action could be reversed by increasing the concentration of the metabolite which has, so to speak, been left out in the cold. The extra molecules of metabolite have a greater chance to elbow the drug molecules off the chemo-receptors.

Drugs of another type that also work by blocking access of a metabolite to chemo-receptors are d-tubocurarine and its synthetic substitute laudexium (Fig. 5). These drugs paralyse the body by occupying the chemo-receptors of the muscle that normally take up acetylcholine, which is the natural message-substance conveying an impulse from nerve ending to muscle fibre. Yet another metabolite-blocking agent is neostigmine (Fig. 5), which prevents the destruction of acetylcholine by the enzyme cholinesterase. Extra molecules of acetylcholine reverse each of these blocking agents and each shares certain chemical features with acetylcholine.

While some drugs therefore appear to act solely by virtue of their distribution to special sites in the body, others act in a double way. Not only are they distributed to special sites, but once attached to the chemo-receptors, they enter into reactions. Thus they act not only passively by getting in the way of a normal process, but actively as well. For example, decamethonium iodide (Fig. 5), a substance which blocks neuromuscular transmission, not only occupies the receptors that normally take up acetylcholine, but enters into a reaction as well. It therefore excites muscular contraction before blocking it and moreover it is not necessarily reversed by an excess of acetylcholine. Again, the phosphorus-containing anti-cholinesterase di-isopropylfluorophosphonate (DFP; Fig. 5) after absorption on the enzyme, destroys it. DFP is therefore irreversible in action.

Ehrlich pictured arsenical drugs as poisoning microbes by a similar double mechanism. "The arsenoceptor and the orthoaminophenoloceptor [of the parasite] . . . come into action equally. Thus . . . the side-chains added to the

FIG. 6. Ehrlich and Hata.

benzene ring act as organs, with which the arsenic-radicle can be forced to take effect upon the different parasites according to the kind of chemo-receptors which are preformed in these parasites."

In short, the organic part of the molecule helps to anchor it to the appropriate protein of the cell, and the arsenical part reacts with and poisons the absorbing protein.

PRACTICAL CHEMOTHERAPY

Since Ehrlich was deeply concerned with the practical uses of drugs, he did not stop with the theoretical aspects of chemo-receptors, but applied his views to practical chemotherapy. "Parasites can only be destroyed by those materials for which they have a certain affinity, thanks to which they are 'anchored' by the bacteria. I describe such materials as parasitotropic. Now all substances which serve for the destruction of parasites are also poisons, i.e. they have an affinity to the vitally important organs and, therefore, are simultaneously organotropic. It at once becomes evident that only those substances can be employed in practice as medicaments, in which organotropy and parasitotropy stand in proper proportion."

In chemotherapy, 'organotropy' expresses itself as toxicity to the infected host and 'parasitotropy' as curative action. Clearly the larger the dose that the host can tolerate and the smaller the dose required to cure, the safer and more efficacious a drug will be. Ehrlich therefore expressed the efficacy of a drug as the ratio of tolerated dose to curative dose, which he called the *therapeutic index*. This ratio remains today the best index of a drug's safety and efficacy.

These concepts grew in a search for remedies for sleeping sickness, which Ehrlich planned along the following lines. First, he established methods of measuring both the curative power of a drug against a trypanosomal infection of laboratory animals and also the drug's toxicity in the same kind of animal. These figures would give the drug's therapeutic index. Then from arsanilic acid (atoxyl), which was known to have some chemotherapeutic action and to be capable of much chemical variation, he made a number of chemical relatives. These were tested for toxicity and therapeutic activity in animals. The results showed which variation was most promising and indicated the next line of chemical modification. In this way Ehrlich approached his target, using chemical synthesis and biological test as gunners may range their guns by firing sighting shots around their mark.

Ehrlich had pursued this plan in his trypanosome work for some years when, in 1909, a young Japanese scientist, Dr. Hata (Fig. 6) arrived in his laboratories, which by then included the Georg Speyer House for Chemotherapeutic Research as well as the State Serum Institute. Hata was expert in maintaining spirochaetal infections in laboratory animals and Ehrlich passed over to him for therapeutic test the range of organic arsenical compounds that he, Bertheim and their chemical colleagues had already prepared. After much thorough work Hata reported his conclusions to Ehrlich, stating that the compound labelled No. 606 was the best. It readily cured spirochaetal infections and had a satisfactory therapeutic index.

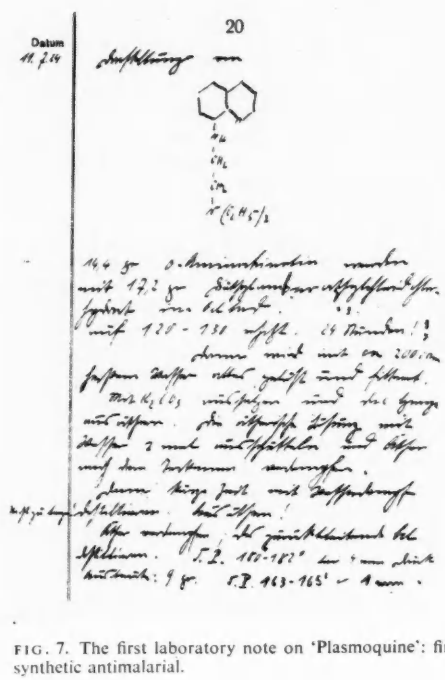


FIG. 7. The first laboratory note on 'Plasmoquine': first synthetic antimalarial.

Ehrlich supervised with tremendous thoroughness the clinical trials of 606 in syphilis and other spirochaetal infections. They were the first extensive trials of a synthetic chemotherapeutic agent, and he encountered many of the snags with which we are now more familiar. When injected into muscles, 606 was liable to cause necrosis at the site of injection; so Ehrlich turned to the intravenous route of administration, then a rarity. Again, if the drug solution was allowed to stand, it underwent a chemical change, becoming more toxic. He therefore instructed that 606 should only be given when freshly made up. Yet again, the water in which the drug was dissolved sometimes contained products of bacterial contamination, including pyrogens which caused fevers on injection, and Ehrlich had to insist that only freshly distilled water was used. In face of these difficulties the correct method of administering the drug had to be worked out empirically. The trials showed that 606 made a great advance in the treatment of syphilis. It was given a name—Salvarsan—and introduced into medicine.

Salvarsan was more than an isolated triumph; it was a signpost, pointing to what might be done in the future. Since the introduction of salvarsan, the discovery of new remedies for infectious diseases has gathered speed. Two of the drugs prepared by Ehrlich in the programme that led to salvarsan have been introduced for clinical use—*oxophenarsine*, which proved a quicker remedy for syphilis, and *carbarsone* for amoebiasis, but most of the modern chemotherapeutic remedies are more indirect descendants of Ehrlich's compounds. They cover and cope with most infectious diseases caused by parasitic flukes and worms, by protozoa, by bacteria and by rickettsias. They include not only synthetic drugs, such as suramin for trypanosomiasis, chloroquine for malaria, dapsone for leprosy and isonjazid for tuberculosis; but they also include the antibiotics such as penicillin, streptomycin and the tetracyclines (aureomycin and terramycin). They even include one drug which is an antibiotic that can be manufactured synthetically—chloramphenicol, originally known as chloromycetin.

* * * *

When Ehrlich qualified in medicine in 1878, he might have counted on the fingers of one hand the available remedies that dealt with the cause of a disease, such as quinine in malaria and fruit juice in scurvy. Today we can begin to count the diseases for which a causal treatment is *not* known. This revolution in therapy would be happening if Ehrlich had never lived, but he did live and he did take the lead in starting it. He had the force of a true revolutionary. "Any theory", he said on one occasion, "is only of account when it can be brought into use through work and not kept hidden away in a chest." His force came through concentration. He described himself as a 'monoman' and he once said "Restrict knowledge to what is really necessary, everything beyond this will do harm." By such rules he narrowed his concentration on to his chosen field, within which his imagination and energy were able to express themselves in thought and experiment, which bore fruit in remedies that have bettered human health throughout the world.

FIG. 8. An early remedy of Ehrlich's was Trypan Red, for trypanosome infection. Antrycide is its modern equivalent, here seen being injected into a sick cow.

To Paul Ehrlich's achievements in the humaner medical revolution, we might apply the words of Andrew Marvell upon Oliver Cromwell's in a broader and crueller revolution:

So much one man can do,
Who does both act and know.

FOR FURTHER READING

Albert, Adrien, *Selective Toxicity*, Methuen, 1951.

Collier, H. O. J., *Chemotherapy of Infections*, Chapman and Hall, 1954.

Ehrlich, P. & Hata, S., *The Experimental Chemotherapy of Spirolloses*, Rebman, 1911.

Fleming, A., "Chemotherapy", Linacre Lecture, Cambridge, 1946.

Marquardt, M., *Paul Ehrlich*, Heinemann, 1949.

Woolley, D. W., *A Study of Antimetabolites*, Chapman and Hall, 1952.

Work, T. S. & Work, E., *The Basis of Chemotherapy*, Oliver and Boyd, 1948.

THE ATOMIC SUBMARINE

The development of the submarine has always owed much to American inventiveness, though it was left to Germany to extract the maximum operational advantage out of this fearful weapon. Now the Americans have won the race to produce an atomic submarine, an advance which is calculated to revolutionise not only submarine and anti-submarine tactics but also the whole of naval strategy.

The first practical submarine was launched in 1775 during the American War of Independence. The designer was David Bushnell, an American. The boat was fitted with a rudder at the stern, a valve to admit water for sinking the vessel, force pumps for driving it out again, and a device for attaching explosive charges to the bottoms of vessels. It was propelled by oars which were operated by men.

Twenty-five years later Bushnell's idea was revived by Robert Fulton. He constructed a boat called the *Nautilus*, which was driven by means of a hand-worked screw and fitted with a copper vessel containing compressed air to give a reserve supply for breathing. This air made it possible for the boat to remain submerged for about four hours. The vessel was tested in the River Seine and off Brest, and succeeded in descending to a depth of 25 feet and placing a torpedo underneath a ship; the explosion dispatched the target vessel.

The first operational use of a submarine dates back to the American Civil War. The South built several small iron boats which were propelled by hand at from 4 to 7 knots and armed with a torpedo carrying 50–70 lb. of powder. One of these primitive submarines, manned by nine men, attacked the Federal warship *Housatonic* and sank her, but was herself sunk by the wave produced by the explosion. Almost simultaneously efforts were being made to develop submarines as power-propelled vessels, and by 1863 the French had succeeded in producing a 146-ft. long submarine which was propelled by an 18 h.p. compressed-air engine. Petrol engines were introduced into submarines by J. P. Holland, an American, and Britain's first submarines were based upon his ideas, with the result that the submarines of the British and American navies at the turn of the century were practically identical. Development of the submarine now proceeded rapidly, and by the time World War I broke out these vessels had become very formidable weapons indeed; upon them the Germans based a ruthless blockade of Britain which later acquired the character of a campaign of indiscriminate terrorism that helped to bring the U.S.A. into the war.

It is worth recalling that anti-submarine measures occupied the attention of many outstanding British, French and American scientists in both world wars. (For example, in World War I, Prof. W. H. Bragg directed one important research team which developed hydrophones and anti-submarine mines; Rutherford contributed several ideas to this research project, which later became linked with the work of top-flight French and American scientists.)

The submarine had become a universally detested weapon by the time the war ended, and after the armistice serious attempts were made, particularly by Britain, to outlaw the submarine by international agreement. The upshot was, however, not disarmament in respect of the submarine arm, but an intensification of programmes for perfecting the submarine.

Radical advances did not materialise however, apart from the Schnorkel device, but in spite of this the submarine was to prove as serious a menace to Britain in World War II as in World War I.

Perhaps the most novel development in World War II was the midget submarine, though anyone familiar with the history of submarines knows that this was in fact a throw-back: midget submarines only 16½ feet long and manned by two men were constructed for the Russian Navy as long ago as 1881, the designer being a Frenchman, M. Goubet, who relied on power from an electric motor driven by accumulators.

As soon as atomic engines could be envisaged, their possible use as power units for propelling submarines was seized upon by quick-witted experts in both Britain and the U.S.A. No information has been released about British plans in this direction, and it has been left to the Americans to make naval history with the launching of the first atomic submarine—the *Nautilus*—on January 21 of this year. Most of the credit for this revolutionary advance must go, not to a team, but to a single individual—Admiral H. G. Rickover, who invested his career in the atomic submarine project and pushed through with it in the face of opposition from most of the high-ups in both the U.S. Navy and the U.S. Atomic Energy Commission. Rickover is a figure of special interest today, for he exemplifies the best type of military technologist, a man who is a technical expert with so much faith in his own judgment that he is prepared to jeopardise his chances of promotion rather than give up an idea which is vital to the security of his country. This attitude is almost traditional in the Services, of course, but it is specially needed nowadays when all too few high-ranking officers are qualified to make decisions on technical questions of strategic significance.

The keel of Rickover's *Nautilus* was laid in June 1952, and the importance of the project was emphasised by the fact that President Truman presided over the ceremony. The work on the submarine's engine had then already started. A prototype engine was built at Arco in Idaho. Known as STR (Submarine Thermal Reactor), this was designed to work with thermal neutrons. The reactor core contains uranium enriched in U235, and is cooled by submersion in a tank of highly purified water—plain water, *not* heavy water, it must be noted. The water serves not only as a cooling agent but as the moderator. Heat produced by the reactor is taken out by a heat exchanger which connects with a boiler where steam is produced to operate a turbine. This turbine turns the propellers.

The atomic submarine represents a really big technical advance which is likely to necessitate a revision of all existing ideas about sea power. The limitations which restrict the operational use of conventional submarines disappear and the range of the atomic submarine seems to be limited only by the endurance of its crew. Its speed is 25–30 knots, which means that it can match the destroyer under ordinary conditions and outpace it in rough weather. It should also be capable of operating at greater depths,

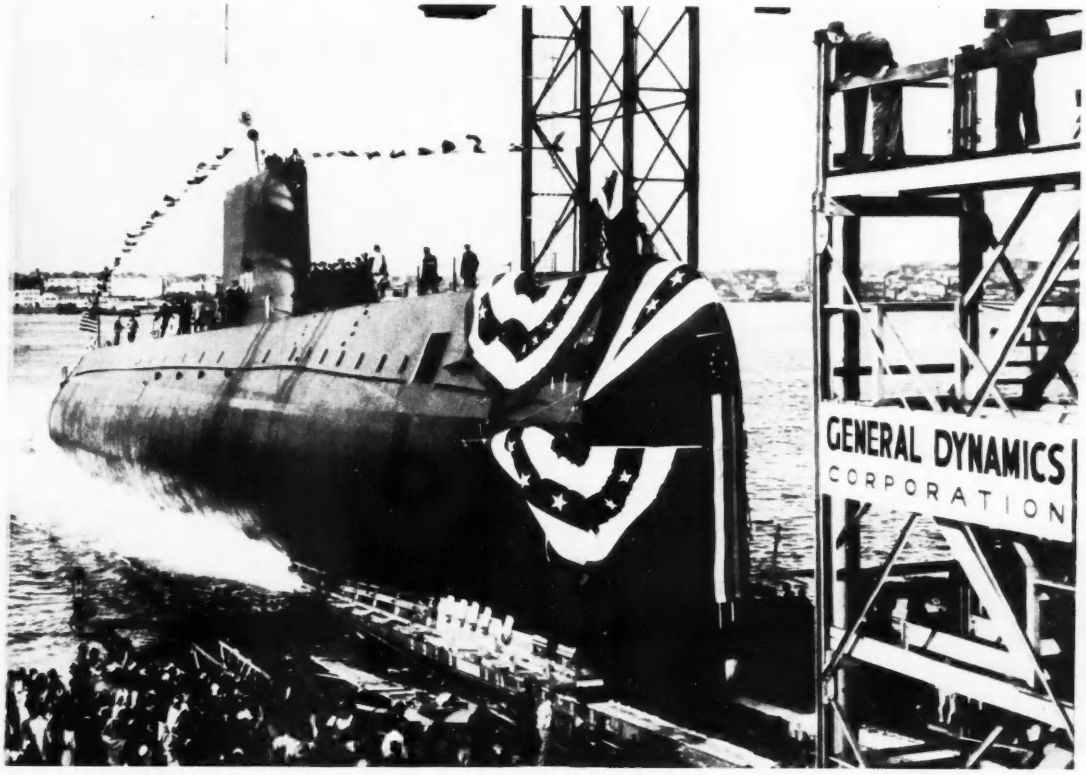


FIG. 1. The world's first nuclear-powered submarine, the U.S.S. *Nautilus*, slides along the slipway after being launched by Mrs. Dwight D. Eisenhower in a ceremony at Groton, Connecticut, January 21.

FIG. 2. Crewmen and shipyard workers line the deck of the *Nautilus*, after the craft's launching.

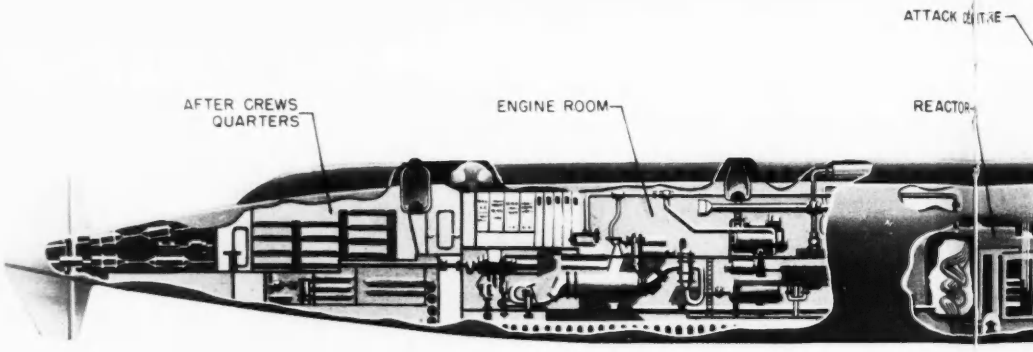
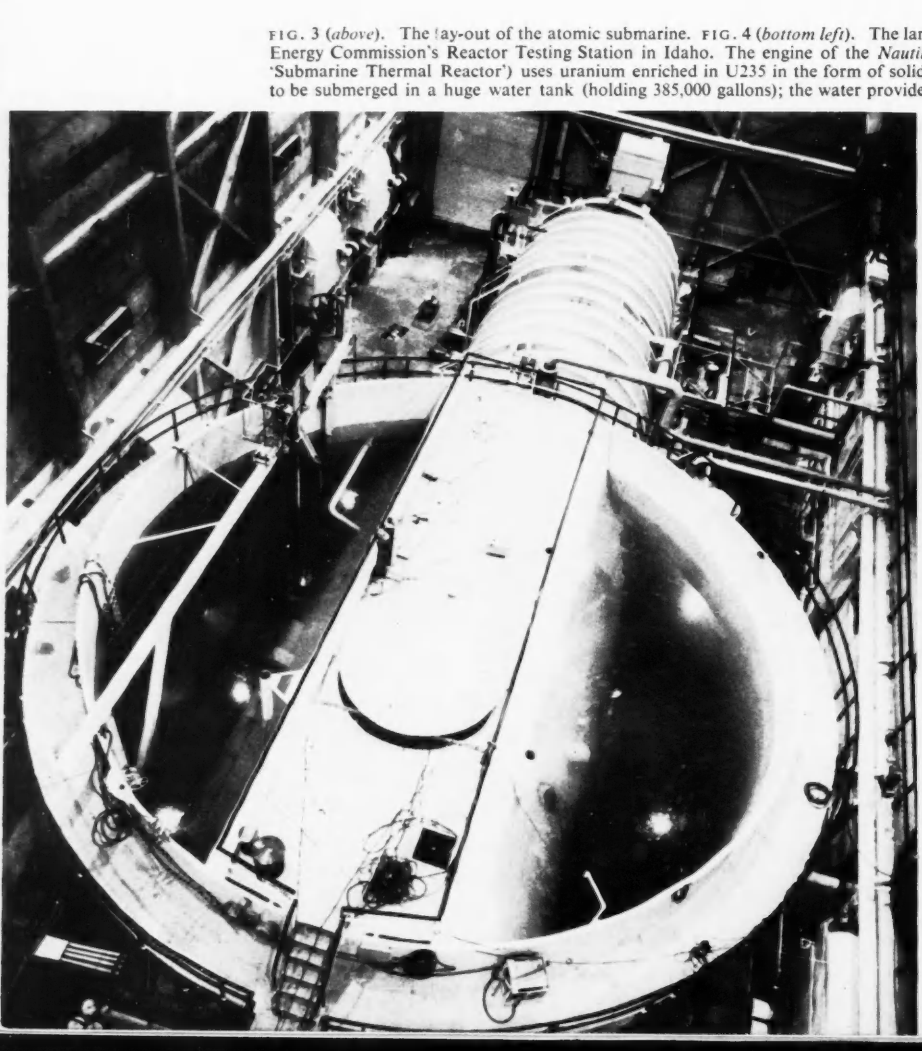
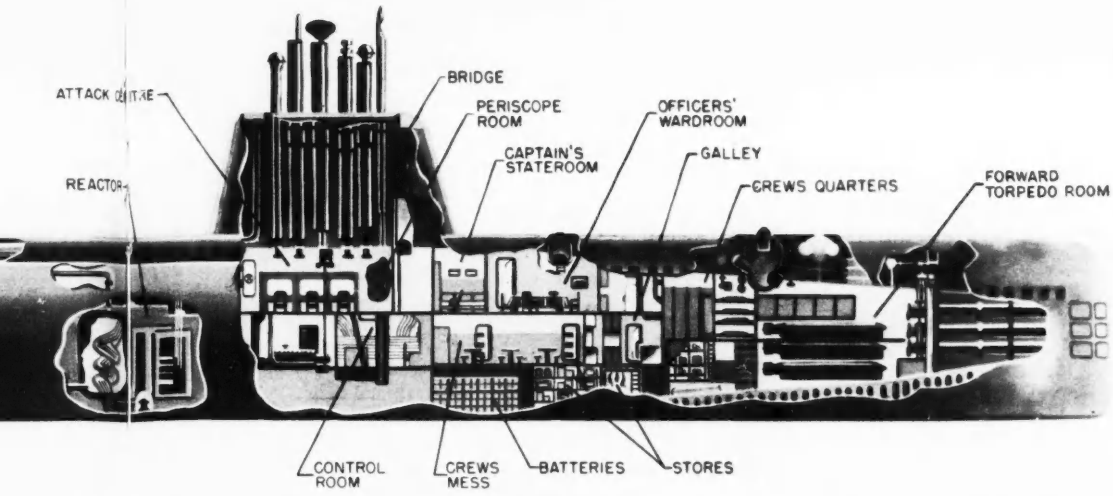


FIG. 3 (*above*). The lay-out of the atomic submarine. FIG. 4 (*bottom left*). The land-based prototype of the submarine's atomic e
Energy Commission's Reactor Testing Station in Idaho. The engine of the *Nautilus* based on this prototype was buil. by the
'Submarine Thermal Reactor') uses uranium enriched in U235 in the form of solid pieces of metal submerged in a tank of very h
to be submerged in a huge water tank (holding 385,000 gallons); the water provides shielding against radiation and also serves to





of the submarine's atomic engine built into a submarine hull was generating power when this photograph was taken at the U.S. Atomic prototype was buil. by the Westinghouse Corporation at the A.E.C.'s laboratory in Pittsburg. For fuel this STR engine (STR stands for ubmerged in a tank of very highly purified water which serves as both a cooling agent and moderator. A section of the submarine hull is seen radiation and also serves to simulate actual sea conditions. FIG. 5 (*bottom right*). Scale model of the STR engine shown in Fig. 4.

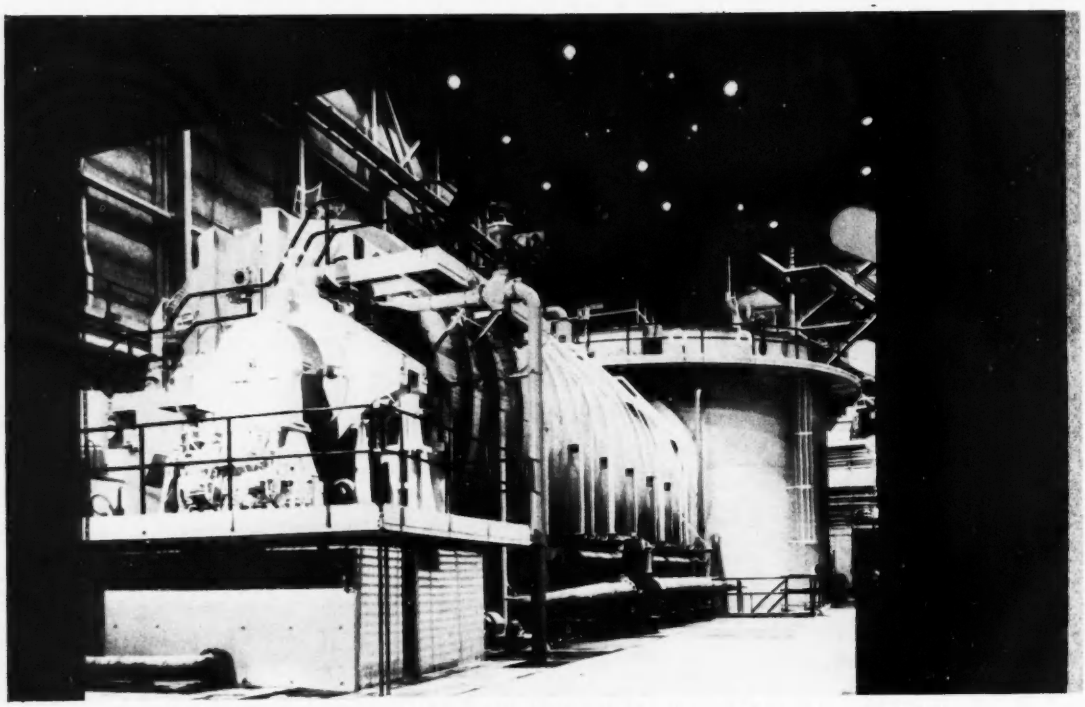


FIG. 6. This view shows the aft end of the hull and the circular sea tank around the reactor compartment.

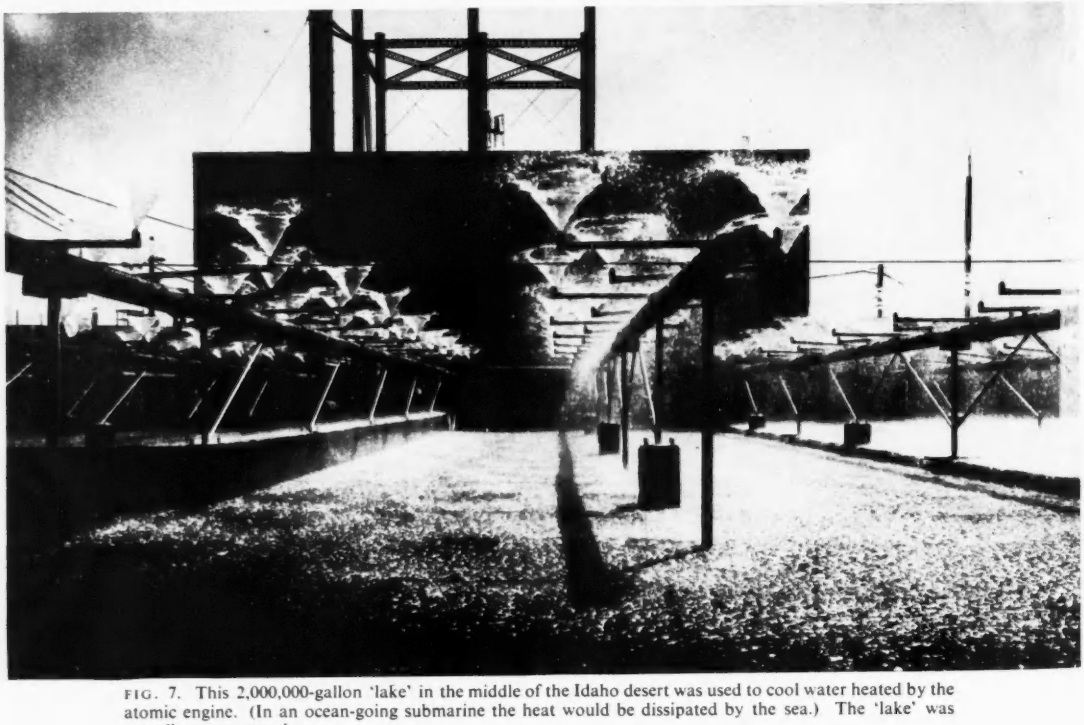


FIG. 7. This 2,000,000-gallon 'lake' in the middle of the Idaho desert was used to cool water heated by the atomic engine. (In an ocean-going submarine the heat would be dissipated by the sea.) The 'lake' was actually a spray pond.

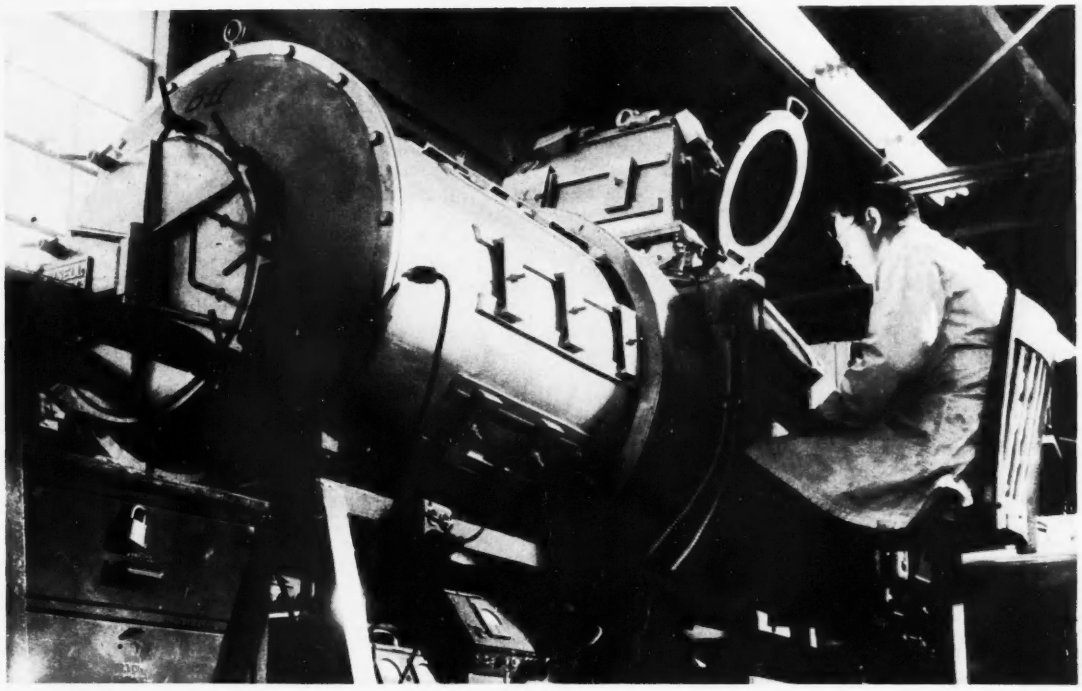


FIG. 8. Zirconium and similar materials used in the atomic engine are tricky to weld, catching fire if welded in the open air. Westinghouse engineers therefore designed this special machine, which is actually a giant vacuum tank. The operator is seen controlling the position of both the welding electrode and the part to be welded.

which would render it less easy to detect (by both surface search vessels and aircraft) and to destroy. The atomic engine requires no oxygen, so the vessel can operate for very long periods under water without need to refuel or to come to the surface in order to recharge the batteries; the Schnorkel device is thus rendered more or less obsolete. The submarine acquires a new striking power; for years the submarine has lost caste relative to the aircraft carrier, for example, but now that trend is reversed. *Vis-à-vis* the atomic submarine, the aircraft carrier is liable to become a flock of sitting ducks.

Many times in the last war submarines were used to penetrate a close blockade by surface vessels. Its penetration power is increased enormously by the increase in speed and increase in range (both vertical and horizontal) which atomic power provides. The submarine has in the past proved devilishly effective when used to sweep the seas of surface warships. The atomic submarine should prove even more efficient for this purpose, but in addition it could be used to bombard coastal and perhaps even inland installations with atomic missiles. It should prove quite practicable to fit rocket-launching platforms to submarines, and the prospect must be faced that submarines will thus become capable of firing rockets with atomic warheads. The development of such missiles would greatly increase the striking power of submarines against merchant ships, though the atomic torpedo and the atomic mine would probably be more effective weapons in this connexion. Against atom-powered submarines armed with atomic weapons there would be little or no safety in the convoy system. One can visualise many ways in which defence against the submarine could be improved, but it certainly looks as though atomic power coupled with atomic weapons has conferred a great (though perhaps temporary) advantage upon the submarine as against all surface vessels. There are indeed some experts who already believe that only another atomic submarine will be capable of catching and destroying a marauding atomic submarine. If this view is correct, then other navies will have to find their Admiral Rickovers and set about organising a 'crash programme' of atomic submarine building before it is too late. A 'Pearl Harbour' attack by atomic submarines could almost cripple a great naval power which had neglected to arm itself both defensively and offensively against vessels of which the *Nautilus* must be regarded as only a very primitive prototype. The Americans already have a more advanced submarine on the stocks—the *Sea Wolf*, whose engine will use neutrons of intermediate speed and molten sodium (or a sodium alloy) instead of very pure water.

There can, of course, be no really valuable peace-time use for an atomic submarine to offset its potential war-time use, but it is perhaps worth noting that the success of Admiral Rickover has given a great fillip to the American programme for developing atomic power stations. The U.S. Atomic Energy Commission has already decided to build a 60,000-kilowatt reactor for a land power station, and significantly it has given the job to Admiral Rickover and Westinghouse who organised the *Nautilus* project.

THE CAUSES OF EXTINCTION

W. E. SWINTON, Ph.D., F.R.S.E.

Life has existed for many millions of years. Estimates vary from 2000 million years to half of that number, but in view of the new estimates of the age of the earth itself (see DISCOVERY, January 1954, p. 23) the former figure may be nearer the truth. Of this immensity only the last five or six hundred million years are represented by fossils in the rocks, but in this time millions of species of animals and plants have existed, great orders of animals like the Dinosaurs, Pterodactyls, Ichthyosaurs and Plesiosaurs among reptiles, and the Titanotheres among the mammals, have arisen, have held spectacular sway, and then have died without progeny. It is this last phrase that is important. We realise that animals, like men, have ancestors who died but left the torch of survival with their offspring. Today there is no lineal descendant, no near relation, of any of the great orders mentioned above, or of many more which are too numerous to mention here.

Popularly, the decline and fall of such notable groups is seen as only part of a great and dramatic past, in which cataclysms on land and sea—volcanic outpourings and gigantic earthquakes, vast upheavals of continental masses and widespread submergence—vied with climatic extremes to stimulate and to destroy the appropriately grotesque life of the times. But was the past so cataclysmic, so liberal with all the accidents of Nature? The answer is an unqualified negative. The past owes much of its popular appeal and its apparently dramatic effects to the immensity of time which the geologist can so easily trace; but in reality living in the past was much the same process as is living in the present, just as geology is really the summation of forces and processes similar to those involved in the dynamic geography of the present. Logically then, one ought to be able to examine the causes of extinction much as one does the causes of death in human beings. Briefly, and not in order of importance, they may be summarised as *pathological conditions* leading to failure in the working of parts of the body; *infectious diseases* and epidemics; *accidents, warfare and self-destruction*. With accidents, those due to man-made objects (aircraft, automobiles and shipping, for example) can be distinguished from those due to earthquake, volcanic products, lightning, drowning and so on. The latter would also include deaths by violence from animals, or poisoning by plants and toxic mineral substances.

Of all these causes only man-made objects need be deleted from the danger list of the past. Animals have always made war on other kinds of animals, and even self-destruction cannot be ignored, unless the lemmings and the Gadarene swine are unique in the annals of zoology.

Obviously all, or any, of these causes could bring about the death of some, perhaps even of many, animals but that is not extinction. Occasionally the inundation of lands or lagoons, an earthquake or a volcanic eruption would wipe out a little community of animals, as it may do today, leading to restriction or even local extinction. This is not, however, the problem we are discussing. Take for example the group of aquatic reptiles known as the Ichthyosaurs. They were free-swimming, their eggs were hatched within the body of the mother and thus these reptiles were free of the land; they were indeed highly adapted for their life. They were active in every sea, and occur in the record from the Upper Trias until the late Cretaceous, a period of over 100 million years. Yet at the end of the Cretaceous period they disappear and none is known anywhere of more recent date. The Plesiosaurs have a somewhat similar history, and the widespread but wholly Cretaceous marine lizards known as the Mosasaurs met with the same fate. If some great chemical change in the waters was responsible for this momentous lessening of the sea's population, it has left no mark in the geological record and the fishes were almost unaffected by it. The Pterodactyls, successful for millions of years in the air, died out at much the same time, yet the birds that flew alongside them lived on and flourished. On the land, with its diverse conditions, the Dinosaurs died out, while many of their contemporaries persisted.

It would seem from these facts that no cataclysmic hypothesis, no argument that postulates vast changes of climate, can really give the answer.

Yet it should be possible to attain an inkling of the lethal process that occurred by observing biological conditions today and superimposing the lessons so derived upon the history of vertebrate evolution.

The factors to be borne in mind are those external or internal to the animals, or a combination of both. *The external factors* are those of the environment, and thus include the geological, geographical and climatic; the effects of competition from other animals and the onset of disease (which may be regarded as an extension of animals and plant competition); the luxuriance or scarcity of vegetation, and so on. All these are ecological factors, in the widest conception of that term. *Internal factors* are those associated with the anatomical and physiological nature of the animal; pathological conditions of which glandular, circulatory or lymphatic disfunction are important; and hereditary factors, as for example those associated with pathological tendencies.

The external characters may be considered first, since it is they that are most frequently considered as the determinants of extinction. Generally speaking, external factors are the biological environment and the geographical. The former is composed of competitors of equal or different grade; pathogenic organisms; and the vegetation.

Competition is an essential part of animal life and, as modern experiments on preservation (particularly those carried out in North America) have shown, attempts to isolate and preserve apparently disappearing species are not very successful. The absence of a sense of danger leads to a lassitude that is often akin to self-neglect. Obviously in the animal groups of the past there was persecution and slaughter, as there is today, by larger or fiercer animals against their less fortunate fellows. Much of this warfare

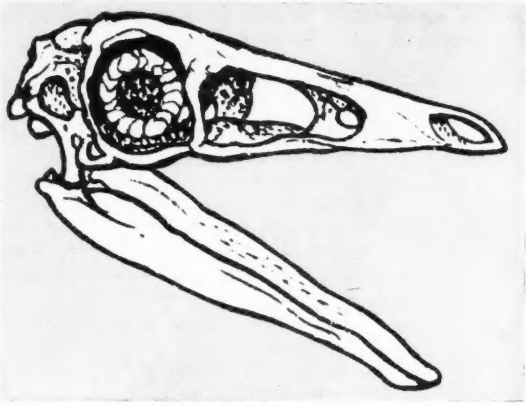


FIG. 1. The skull of *Struthiominius*, a late Cretaceous carnivorous dinosaur with toothless jaws. Skull is 10 inches long.

is obvious, some more obscure, such as the effect of egg sucking or egg stealing. Yet all of these factors operate at the present time against the reptiles and the primitive mammals called Monotremes without producing extinction on groups that are admittedly mere shadows of their former selves. Apart from the purposive slaughter of animals by man, as instanced by Dr. Arthur recently in DISCOVERY (January 1954), such oppression does not seem to have the same results in Nature. One has only to see the condition of wild life of all kinds in Africa today to realise that this is not one of the causes of extinction of the kind we have in mind.

Disease is, of course, a similar condition where the host is infested and ultimately perhaps destroyed by the activities of the invading organisms.

The effects of trypanosome infection in African horses and cattle are well known in nagana and souma, and the bloodsucking fly, *Glossina*, that transmits these diseases and human sleeping sickness is known fossil in the Oligocene, so that these diseases may have been potent reducers of the numbers of the horses and cattle of the plains during the Tertiary. Yet such infestations leave little if any marks upon the bones and would be undetected in past generations. Where disease is seen, in such cases of osteomyelitis, osteoarthritis, haemangiomata, and so on in Dinosaurs, there is no evidence that their effects were more lethal or more widespread than they are today. There are certain postures assumed by the dead that suggest various infections; for instance, the backwardly bent vertebral column and retracted limbs suggest tetanic or strychnine convulsions or an injury to the central nervous system. Many fossils from all vertebrate groups show such conditions, but they carry no wider implication than do such fatalities at the present day.

The effect of plant life may be more important. Baldwin has drawn attention to the lengths to which some suggestions go, in the idea that the great reduction in the number of ferns (and thus the beneficent effects of their *Filix mas*) may have led to the death of the vegetarian Dinosaurs through constipation! This is unlikely but there is little doubt that these same Dinosaurs, Sauropoda and Ornithopods and Armoured Dinosaurs were conditioned to a predominantly evergreen vegetation; they may even have been able, according to Nopcsa, to digest resin from conifers. The advent of the newer kinds of trees in the early Cretaceous, especially as many of them shed their leaves in the autumn, may well have produced widespread effects on its consumers. Yet there is little evidence that the effects were *racially* severe. The occurrence of noxious seeds and poisonous berries would be of no more importance than it is today.

In general, therefore, there seems to be no foundation for any suggestion that extinction was caused through the biological aspects of the environment.

The geographical factors may briefly be enumerated as: diastrophism, those geological actions that have resulted in the differential features in the earth's surface, and under which continental connexions and land-bridges and isolation may be considered, together with the general results of continental change, such as climatic variations and the effects of excessive cold or heat and changes in humidity. Here it must be confessed there is a considerable history of belief in the efficiency of these factors and especially for the almost determinant part of the Cenomanian transgression, as it is called, when during the Middle Cretaceous there was considerable encroachment of the waters on the land.

At first sight there is much to be said for the thesis. In Australia there is a well-known and accepted example of the powerful biological results of geographical isolation. A typical Marsupial fauna, long extinct almost everywhere else and but briefly encountered in the geological record of other regions, has flourished and diversified itself until the advent of man and his introductions started the destruction of the native fauna. This at once suggests the vulnerability of settled stocks of animals to invasions by other more advanced kinds through geological agencies, such as land-bridges

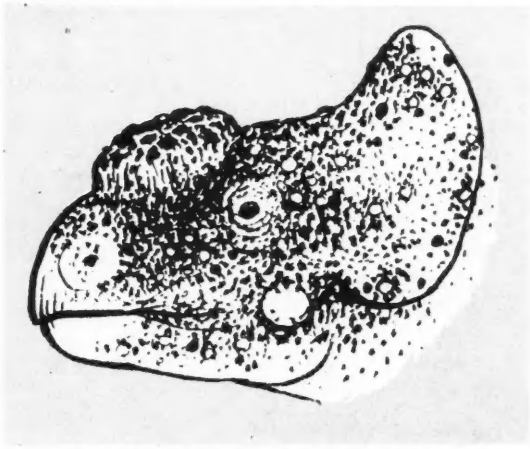


FIG. 2. *Pachyrhinosaurus*, a late Cretaceous horned dinosaur, in which the place of horns was taken by the battering-ram of nasal bones 10 inches thick. The brain is shown solid black.

FIG. 3. Skull of *Inceratops*, an armoured dinosaur, a late Cretaceous horned dinosaur. Skull over 6 feet long of which half is a bony frill over the neck.

While there is a good deal of evidence for the dispersal of groups by such means and there is also palaeontological support for the disappearance of other groups as a result, the fault does not necessarily lie with the diastrophism.

The failure of all this geological and geographical argument lies in the assumption that the great disappearances were sudden and associated. If, however, one takes groups such as the Dinosaurs, one finds that apparently important families or sections were leaving the field at intervals all along the route, and that many of the most important had already disappeared before the Cenomanian transgression. It is said that the Ichthyosaurs and the Plesiosaurs died out, leaving the fishes in command of the sea. But the exit of the Ichthyosaurs and the Plesiosaurs were not contemporaneous. The greatest achievement of the latter was in the Upper Lias, and the Upper Cretaceous forms were of a quite different kind. The Pterosaurs were also differentiated into the Jurassic Rhamphorhynchoids and the mainly Cretaceous Pterodactyloids, with only two large-headed forms surviving anywhere near the end of the Cretaceous. The fishes that survived the disappearance of the Ichthyosaurs and the Plesiosaurs were by no means the same as those that were dominant at the beginning of the Trias or even the start of the Jurassic.

All of these facts lead to the conclusion that diastrophism has not of itself been a general cause of extinction, though this is not to deny that it could have accelerated the process. The Cenomanian transgression produced a wide advance of the seas in Europe, Asia and North America; by flooding the low-lying lands and deepening the haunts of the giant Sauropodous Dinosaurs it must have speeded the departure of many, but this company of animals had earlier reached its maximum and was already on the wane except in some parts of the Southern Hemisphere. The contrary condition, the uplift processes of the Laramide Revolution of later times, was of much greater effect, but its operations were specially important because of the previous history of much of the North American fauna. For long there had existed a vast extension northward of the Gulf of Mexico, forming a great inland sea on whose low-lying banks were the carnivorous and armoured Dinosaurs, and in whose shallow waters were the amphibious bipedal Hadrosaurs. Most of these were of late Cretaceous age, but by the Lance formation* only the largest and the most heavily headed still persisted and they were doubtless aided in their extinction by the gradual rise of the land with the disappearance of the inland sea and the everglades around it. Yet this process must have been slow, and it is doubtful if in such conditions any widespread and sudden destruction of the forms could take place. Nor can it be claimed that concomitant alterations in temperature and humidity have played a specially lethal part. They may help to explain the restriction of range and speciation of modern crocodiles, but these reptiles are by no means near extinction from geographical causes. It can now be pointed out that recent investigations, by Cowles and Bogart in Florida, on alligators have revealed an unexpected tolerance for lower temperatures than those normally considered essential for these reptiles, and the experiments indicate that the Dinosaurs were probably less susceptible to temperature change than has generally been assumed. Rodbard has recently discovered that cold-blooded animals have thermosensitive brain centres that affect their blood pressure and other functions. These have been demonstrated conclusively on Chelonia so that no longer must we assume that the reptiles of the past were wholly at the mercy of their climatic environment. There seems little doubt that the slow tempo of general changes due to diastrophism could be met by animals with physiological resilience, whether the enemies were geographical or other animal competitors.

Perhaps the word resilience may yet provide the clue. It can be argued that a young race of animals has a good deal of evolutionary potentiality and is therefore ready for any kind of tussle with the environment, with the ability to diverge and become more progressive. The human youth helps to exemplify this as one whose future could lie equally well in many different directions in his special background. Conversely, old age, with its loss of adaptability, can be observed, not only as individual senility but

* The Lance formation is the Upper Cretaceous Continental deposit of Canada and the United States famous for its dinosaur deposits.

FIG. 4. The reconstructed head of *Pachycephalosaurus*, a dinosaur, with superimposed reconstruction of brain. The skull above the brain is solid bone about 9 inches thick.

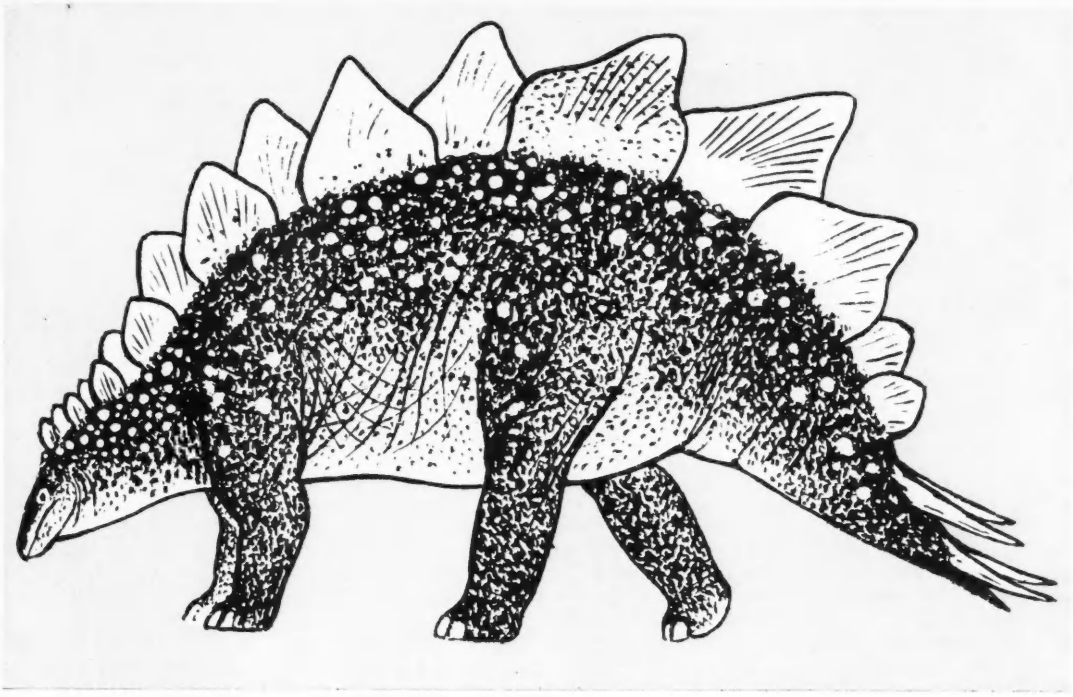


FIG. 5. *Stegosaurus*, the 'plated lizard', an armoured dinosaur that shows bony plates along the back. They have no connexion with the underlying skeleton. *Stegosaurus* occurs in the Jurassic of Europe and America. Original 25 feet long.

a widening of those symptoms until whole groups and genera are affected with what has been called phylogeronty. This has also been denied in some quarters.

Smith Woodward, in 1910, in a presidential address to the British Association, pointed out certain traits that were common to a number of fossil vertebrates which the geological record showed to be on the verge of extinction. He singled out four special features: *giantism*, exemplified by the Mesozoic Sauropodous Dinosaurs and the early Tertiary Titanotheres; *spinescence*, again demonstrated by certain Dinosaurs and the early mammals; *loss of teeth*, seen in Dinosaurs, Ichthyosaurs and Pterodactyls. The effects of its early occurrence in the Chelonia were perhaps minimised by the development of a secondary bony denture and some Dinosaurs reacted in a somewhat similar way. Such genera as *Genyodectes*, *Oviraptor* and *Struthiomimus* are quite edentulous, and there are other reptiles and mammals with similarly poor dentitions. The last factor cited by Smith Woodward was the degenerate form, the eel shape, adopted by senile families of lower vertebrates.

Undoubtedly these observations show signs of an ageing of stocks as well as individuals. Where I would venture to differ in the appreciation of the four characters is in the attribution to senility as the cause of giantism and spinescence. I believe that these were due to disorder of the pituitary gland. There are many instances of giantism in the Dinosaurs and early mammals where the cast of the brain-cavity and the size of the hypophysial cavity suggest an unusually large and presumably active pituitary gland. This is also the case in many Dinosaurs and Titanotheres which develop an overgrowth of useless (i.e. non-functional) bone. Most of this spinescence is quite inexplicable on any other theory and detailed growth studies show that much of this excessive material is out of proportion to the rate of growth of other bones or parts of the body. None the less, it must not be forgotten that throughout their long history the reptiles have shown a marked propensity for the development of paired series of bones on the dorsal—and sometimes on the ventral—surface of the body, and to this and not to any pituitary action were due the spines in the skin of the back of *Stegosaurus*, whose ridiculously small brain shows only a small pituitary region.

I have laid the blame for the giantism and spinescence at the door of the pituitary, but it has to be remembered that that gland is in intimate relationship with the other ductless glands and that the pituitary-adrenal complex is difficult to unravel in its actions in the long-vanished physiology. There is no doubt that disorganised endocrine action would produce hormone vagaries leading perhaps to an overgrowth of bony structure. These growths might themselves be of disadvantage to the animal apart from their evidence of disfunction, just as the increase in limb and jaw length in the primitive Proboscidea would have proved dangerous until these animals were saved by the growth of the trunk.

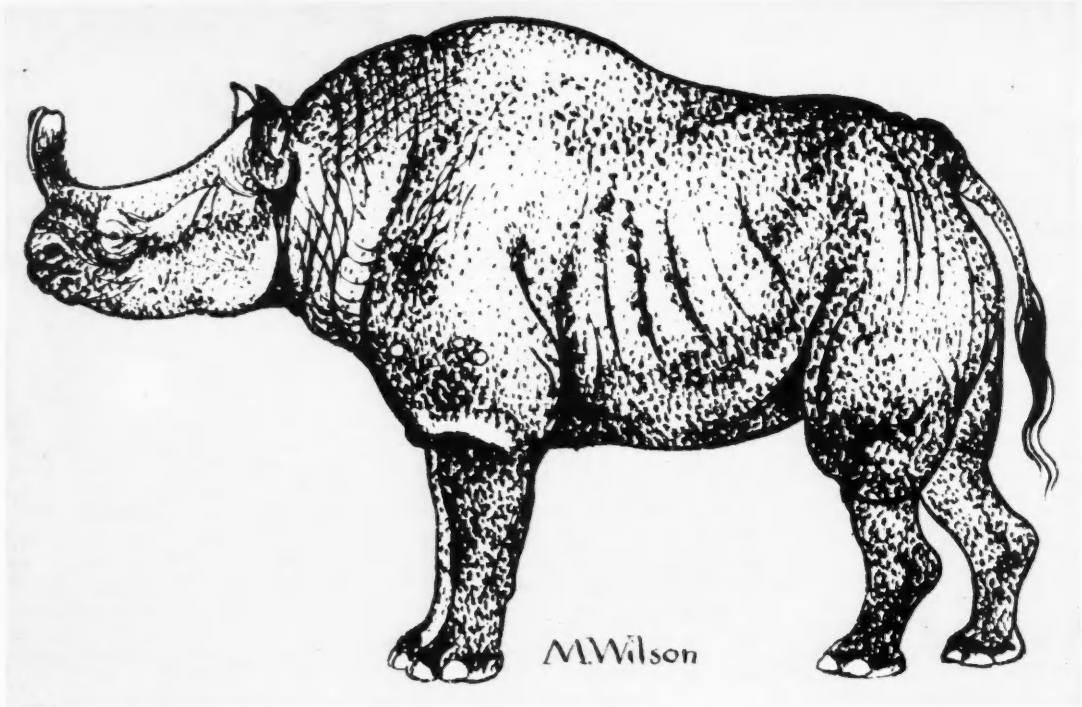


FIG. 6. *Brontotherium*, a large horned mammal (a Titanothere) from the Oligocene of North America. Original 10 feet long.

The structures can be taken as evidence of lack of physiological balance and an indication that their possessors were at a disadvantage in their struggle against the environment. I always think that a London underground train furnishes a good simile for this kind of process. While the train is in motion it is seldom that the air compressor is heard, but very commonly when standing at a station the pump is working noisily. When a well-adapted organism is functioning all is well, but when its evolutionary speed decreases, the hormones take up the current with remarkable results. These would also affect breeding rates and even produce sterility.

The major evolutionary periods in the history of the vertebrates are three: in the Devonian, the Permo-Trias and in the Cretaceous-Eocene. These are not coincidental with the climacterics of the invertebrates. Each may appear to be a sharp line in the history of life but in fact covers a period longer than that required for the whole history of *Homo sapiens*. All these times were periods of disappearance for many groups, some of which left portentous offspring, while others were barren and extinguished. They were equally times of great evolutionary radiation.

These contrasting events would seem almost to be self-explanatory. Old and more or less effete groups were swept away by the infiltration of new and more adaptive types. In other cases it was a replacement rather than a conquest; and perhaps in both cases the major cause of the disappearances were to be found in the physiological make-up of the animals involved. Most of the circumstances can be witnessed in human affairs today. What is certain, taking invertebrate and vertebrate histories together, is that diastrophism was not the principal cause.

A combination of internal factors caused many of the animals to be unduly sensitive to other, environmental, changes. Extinction was not, therefore, a mysterious dying out and the verdicts in most cases of the extinct groups must be 'death from natural causes'.

READING LIST

Baldwin, E. (1949), *Introduction to Comparative Biochemistry*, Cambridge U.P.

Cowles, R. B. and Bogart, C. M. (1944), *Bull. American Mus. Nat. Hist.*, **83**, 265.

Lull, R. S. (1947), *Organic Evolution*, Macmillan.

Rodbard, S., *et al.* (1949), *American Journal of Physiology*, **158**, 135.

Smith Woodward, A. (1909–1910), *Report, British Association* (Winnipeg Meeting), 462–71.

Swinton, W. E. (1939), *Proceedings, Geologist Association*, **50**, 135–46.

Swinton, W. E. (1948), *The Corridor of Life*, J. Cape.

FILMING BADGERS AT NIGHT

H. R. HEWER AND ERNEST G. NEAL*

There is always a fascination about the night. The first slight stirrings of animals, which have been sleeping all day, gradually replace the dying sounds of bird song and the activities of man. To the zoologist there is the added challenge of trying to find out what is happening in the dark, to build up a picture of life in a totally different community in which the senses of smell and hearing play the part of sight. For many years naturalists have 'watched' in the dusk and dawn and have collected moths by the aid of light, but still the knowledge of what goes on is negligible and much that is said and written is merely guesswork. In September 1950 it occurred to us that we might be able to observe and even take film records of what we saw by the careful training of nocturnal animals to light. Badgers were our chosen subject, largely because we knew, or thought we knew, quite a lot about their ways already.

The biological problem of training wild animals, which were free to come and go as they pleased, were shy of man, and, like all nocturnal creatures, retiring in their ways, were only too apparent. By defining and limiting our practical problems of observation we had to try and shorten the odds against us somehow. We needed privacy (freedom from interference) and a good electrical supply not very far away. The set where the badgers lived should be among trees to support the overhead lights, and be reasonably 'observable', that is, not on a very steep slope or in a dense thicket.

By January 1951 the site had been found, in nearly every way perfect, very photogenic and almost halfway between our two homes (we lived 150 miles apart!) The badgers were 'at home' in the best part of the set and had cubs down below. The only snag was that, as at all sets, there were a lot of other holes into which they could move if they did not like any lights at all. However with cubs in the nest chamber the sows *could not move*, and we banked on this to give us a chance of training at least the females to tolerate light. Tolerating noise was to come later, for we realised that however much the camera was silenced, in the dead of night at a few yards distance, it would sound like a machine gun to the sensitive ears of the badgers.

For lights we should want eventually 1000-watt bulbs about 7 to 8 feet above the ground. Each would illuminate an area of about 3 yards diameter and we should want enough to cover a reasonably large area up to the limit of our power supply. Even with this apparently dazzling light, the fastest possible film was necessary if we were to get the depth of focus to cover the movements of the badgers and the use of telephoto lenses for close-ups.

The next two months were a scramble to get the necessary equipment together and assembled. The lamp-holders had to be made from aluminium for lightness and thoroughly water-proofed to withstand all weathers. In one hectic week-end at the beginning of March we installed the overhead supporting wires, the distribution box with separate fuses for each lamp, and the lamps and their cables, and finally, as dusk settled down on the Sunday evening, the main supply cable was run back to the power point and connected up. Into the huge lamp-holders were placed 25-watt bulbs emitting a mere fraction of the light that was to come, but, even so, stronger to the eyes of the badger than the brightest moon.

Every night the lights were switched on at dusk for about two hours so that the badgers would have to get used to them and find that they did not portend danger. For this reason we kept away lest the scent of human beings should become associated with the lights—and to human beings badgers have a well-established and understandable reaction. After several weeks, 60-watt bulbs replaced those of 25 watts; then, early in April, 200-watt bulbs were used. At this point we allowed ourselves an inspection. What a thrill to see coming out from the hole, not long after the normal emergence time, the boar followed by the sow in light conditions such as never before. Every hair, every sensitive twitch of the nostrils were visible as they suspiciously tested the air for danger. Their behaviour, however, was not quite normal. They seemed to be waiting for something. They were doing nothing in particular and after a little while they went down. Were they waiting for the lights to go out? If so, they were to be disappointed because from this time on, we kept the lights on all night. Several holes which were not being used were blocked up and we linked up with the lights a small motor which would produce a whirring note like that of the camera, so that the training for sound could begin.

So far, so good. Only a small cloud on the horizon was visible and that might come to nothing—a family of foxes (vixen and cubs) had moved into the lighted area of the badger set, and badgers do not appear to like the dirty habits of foxes.

AWKWARD FILM STARS

We had hoped to start continuous observation at a long week-end in the middle of May when the cubs would have been above ground for nearly a month and would be very active and playful. So much for plans. By the end of April the badgers had moved *en bloc* to a different part of the set fifty to eighty yards away and had excavated about a quarter of a ton of chalk to make their new home comfortable! Had the new sound unduly disturbed them? Was the nearness of the foxes too much? Or were the continuous light and 500-watt bulbs the last straw? We cannot be certain, but the result was disaster unless the badgers could be shepherded back to the lighted area. Their new home was on a prehistoric burial mound. Their archaeological enthusiasm was undoubtedly praiseworthy but not held in high esteem by us.

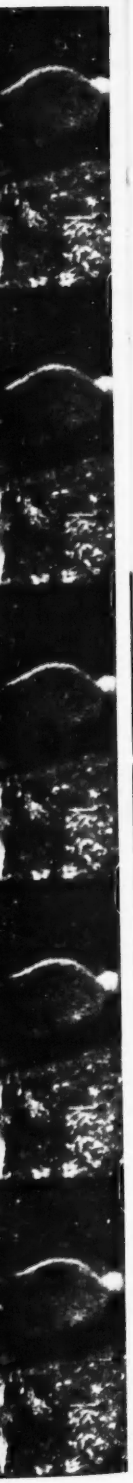
The Friday evening of our critical week-end was, therefore,

* H. R. Hewer, who is Assistant Professor of Zoology at the Imperial College of Science & Technology, London University, has collaborated in making a film, now completed, with Mr. Neal, whose book *The Badger* (Collins, 1948) is already a classic. Mr. Neal is head of the Science Department at Taunton School. The badger film they have produced will be seen on television soon.

FIG. 1. H. R. Hewer manning the cine-camera which was completely enclosed to reduce sound to minimum.

FIGS. 2 and 3. The Warminster badger sets where the other cubs were filmed.

FIG. 4. A strip from the badger film, the sow with one of her cubs—both are completely habituated to intense light and the sound of the camera.



lm, the sow with
etely habituated
of the camera.

spent in watching, not only the lighted area, 'just in case', but also the burial mound until the badgers had all left and wandered away. About midnight, their holes were blocked so that they had to find somewhere else to go on their return. Round about dawn these holes were watched again because a badger, faced by a blocked hole, may in a matter of a few minutes dig round the blockage, pull out logs and, in fact, perform prodigious deeds unless interrupted. As a result, we felt pretty certain of having *some* badgers in our part of the set and perhaps one or two of them might use the lighted holes. But even if they tolerated light they did not like it and we had been forced to interfere to give ourselves a chance, however small.

Thus all our hopes were centred on the following night. At 4 o'clock in the afternoon a thunderstorm burst and although the noise was over by 7 p.m. the rain continued to pour down relentlessly. We had not intended to film in the rain had everything else gone well, but to have our remaining ray of hope blotted out by rain was too much, and we decided to go on. An umbrella was slung up to protect the camera; nothing else mattered. Badgers do not seem to have very strong feelings about rain although it may stop them emerging if it is very heavy and they are not very hungry. Anyway some of the cubs did come out of the unlighted holes and one came under the lights. We had secured our first few feet of film! And apparently the noise of the camera had not worried the cub. We were soaked to the skin—but happy. Moreover, we had been able to block some more holes when the badgers were out and we hoped for greater things on the Sunday night.

Alas for these hopes! By the afternoon, the wind which had been S.W. and favourable, backed to S. and showed signs of backing further. By nightfall there was very little wind but what there was was S.E. and by dawn had backed to N.E. An easterly wind blew scent straight from us on to the set, and all through the night we were frustrated by seeing the cubs approach the entrance, catch a puff of tainted air, and dive below. On the few occasions when a cub remained visible for a second or two, the camera noise sent it dashing back to its hole in a rush. The noise of the rain in the trees the night before must have completely covered everything and we were hoping for far too much.

What could we do? During the following week we made a temporary cover for the camera which deadened the mechanical noise a good deal. We also decided to move back about five feet so that our average distance would be 30 feet instead of 25, and to build a 'screen' in front of the camera composed of blankets further to deaden the sound. By the Friday, of course, the badgers had reopened some of the blocked holes near by, but had not, thank goodness, returned to the burial mound. A little gentle shepherding in the pale light of dawn sufficed to ensure that there were at least four badgers down below our lighted area.

During the following nights success came to us, but only with the cubs. At first they were still doubtful about the noise of the camera, but they soon learned that no harm came to them, and on the last night behaved perfectly normally, without a sign of hesitation. Fortunately for us, the wind remained gentle and south-westerly so that everything was in our favour. One cub gave a performance that we had hardly hoped for. Normally they trot some distance into the wood and root among the leaves and beech-mast for food. But this little cub stayed on the platform outside the holes and systematically worked over it for about three-quarters of an hour. During that time nearly two dozen edible objects were found including snails and cockchafers; the latter had been attracted by the lights and flown against the bulbs, to crash with a thud on the ground. From the photographs taken we were able to make a film which lasted about eight minutes, but it showed only the cubs.

From the experience gained we hoped to be able to modify our approach in 1952 to train the adults also. This time we started the sound training much earlier and imitation camera boxes were installed at the same time as the lights in the early spring. These boxes were distributed through the wood so that whether the badgers used the lighted holes or not they would still be trained to sound. Again we had evidence of badger families; heaps of bedding material gathered to the holes, plenty of droppings and fresh food scrapings in the wood. This time we started with 60-watt bulbs since the light did not seem so important as sound. As the weeks passed, occasional inspections were made, and we regretfully came to the conclusion that all was not well. Quite certainly some of the badgers had left the set, and in all probability only a sow and her cubs remained. When we came to make the attempt to take film records in April, our worst fears were realised. Only one sow badger remained with her cub and she was highly sensitive and shy, and could not be induced to come anywhere near the lights. We hoped on for a fortnight and then gave up. So far as we could guess with reasonable certainty, the badgers had early on reacted to the light and sound as they would do to the actual presence of man; perhaps they had associated these factors with man after their experiences the previous year. Anyway, we decided to make no more attempts at that set, and began looking for an alternative.

Soon we were told by Major Maxwell Knight of a set known to him where he thought we stood a chance of success. The badgers had never been persecuted or interfered with, and some of them used to visit the dustbin of a nearby house and feed on the scraps in the light of the kitchen window. The site was only 25 miles from the home of one of us and could, therefore, be easily visited. Our plans were laid afresh. This time we had to build a raised stand from which to photograph and, as there were not many trees, the supporting wires were difficult to arrange. But by the end of February all was ready for the training period. For several weeks previously, food scraps had been put out near the holes and the badgers had learned to feed there instead of at the dustbin. Now, food scraps were put out only when the lights were put on, so that the two events would become associated. Even on the first night of lights (60-watt bulbs) a sow emerged almost at the usual time. She was nervous and easily frightened by noises such as a train or car, to which she normally paid no attention, but it was a promising beginning. Later inspections showed that several badgers including the sow with cubs and a boar, would come right underneath the lights and feed.

By the end of March 200-watt bulbs were tolerated and we thought it was safe to introduce the new factor of the camera noise. This time it was to be the real thing, operated personally. We wanted to be sure that the badgers would

learn it had no danger for them. At first the camera was run when the noise of a train or an aeroplane partly deadened it. Food was rolled down the holes so that we could hear the badgers eating under cover, and the camera could be heard by them before they had committed themselves to the open. The camera was also run when the badgers could be heard scuffling in the thick rhododendron scrub which surrounded the more open part of the set. On April 13th the boar came out under the lights and fed within 25 feet of the camera, and when the whir of mechanism started he paid no attention to it whatever. Now, with one exception, all was ready. During the training period several of the badgers had emerged from the holes under the lights, had fed in the lighted area and even returned to these holes. But many of the other entrances of the set had been used frequently. Our problem, therefore, was: *how to compel the badgers to use our lighted area* and the holes within it, and not any of the many other entrances (nearly twenty in all) either among the rhododendrons, or otherwise out of sight of our stand. Somehow, without frightening the badgers, we had to stop up these other holes, all of which were connected with each other underground.

It has long been known that if a stick is placed across a badger hole it is brushed aside by the animal without any sign of nervousness. Presumably, it is considered by the badger as a natural hazard; indeed, twigs and small branches are always falling down and might well lie across the hole without having been purposely placed there. We decided to extend this 'accident' and see whether a mass of twigs and branches, sufficient to make entry or exit difficult and laborious, could be placed across an entrance without causing alarm to the badgers. Across one hole often used by the sow, within sight but outside the main illuminated area, we dropped a heap of rhododendron twigs and branches, cut off from the shrub surrounding it. The following night, a sow which had emerged elsewhere came back with the obvious intent to go down this hole. She took one glance at the blockage, turned towards our stand and trotted straight up to one of our well-lighted holes and went down within 15 feet of us. Here was the answer to our problem. The badgers tolerated our lights but did not *prefer* them. Now we could make them choose these holes because they could not get in and out of the others easily. So all the other holes which we knew to be commonly in use were blocked with twigs of brushwood or rhododendron. These blockages had to be kept in repair because after a few days a badger would force its way out and thus make it easy for its fellows to follow suit.

It is usually about the middle of April when a sow brings her cubs above ground, and we aimed to maintain continuous observation from dusk to dawn each night from April 18th onwards, beginning to film as soon as we felt we knew enough of their movements to be sure that the lights were in the best places. All went well. Some adjustments were necessary and the lights were spread out over a wider area than we should have liked, but filming was still possible.

It is often thought that achievement after long and laborious preparation comes as an anticlimax. This was certainly not so in our work. Partly because there was the constant battle of wits to make the badgers use our lighted area, but mostly because we had the thrill of seeing in good light the behaviour of the sow as she encouraged her cubs to come above ground. There was excitement and to spare throughout the period of filming. How many cubs were there? For several nights we only saw two. Then we realised there was a third which was rather more timid and less venturesome throughout the time we watched. The boar, which had been a fairly constant visitor to the lighted area, had not been seen since about a week before the cubs came above ground and we never saw him again. One incident will long remain in our memories as well as on celluloid. The three cubs were nosing around the entrance about 15 feet in front of the stand, when the sow came out, passed between them and trotted away into the bushes. The cubs then gradually ceased their activity and went below to await her return which would give them the confidence to re-emerge.

As the days passed, the cubs became more adventurous, wandering out into the surrounding shrubbery even when the sow herself was away foraging. Sometimes the timid one would accompany the sow while the other two rooted about on their own. Another incident which occurred within view but out of the intensely lighted area—and so was not filmed—was the sight of the sow standing in a narrow path between the bushes, watching the now older cubs play and romp in the open space in front of her. Apparently satisfied that all was well, she turned and trotted off with the timid cub, leaving the bolder two to wander off into the shrubbery on their own.

Our efforts to keep the activities of the badgers fairly well circumscribed led to an interesting development. All along we had been conscious of other badgers besides our own selected family, but as they used the thick rhododendron shrubbery it was very difficult to know how many there were. As we blocked more holes successfully, we forced these into the territory of our family, and we were able to identify the invaders as a sow and her two cubs. This invasion caused trouble; trouble to the badgers and to ourselves. Two fights took place between the sows, outside the range of the strong light so we were not able to film them. Nevertheless, a sound record of them was made, and very impressive it is too. Eventually the congestion proved too much and the invading sow came back one night and led her cubs out in a most determined and purposeful way, not to return.

By this time, pressure of other work prevented us from continuing the intensive night observation. But we were well satisfied. For the first time, nocturnal wild animals had been filmed by training them to tolerate strong light and a new unusual noise, and an extremely interesting record had been made of the behaviour and activities of the badgers under as nearly natural conditions as is possible.

MAN'S ECONOMIC INTEREST IN PLANTS

by

WILLIAM E. DICK
B.Sc., F.L.S.

FIG. 1. Greek coin *c.* 350 B.C. showing harvest-mouse on an ear of barley.

The fight against hunger is a campaign which has gone on for centuries and which is not within sight of a decisive conclusion. It is a global campaign with its own special strategy, tactics and logistics, and it can only be won if this fundamental point is generally accepted: "if you want to be successful the rules of biology come first and the rules of engineering and administration come second" (Prof. S. C. Harland, DISCOVERY, Oct. 1951, p. 309).

Of fundamental importance to all interested in this field is the subject known as *Economic Botany*, a vast subject that covers not only food crops but also all the other plants for which men have found uses. A good knowledge of economic botany is indispensable if we are ever to secure the best possible exploitation of the plant wealth on this earth. In the deployment of agricultural resources it is as indispensable as, say, geopolitics is in political planning. Yet, like geopolitics, it is a neglected subject; for example, Vavilov's classic analysis of the centres of origin of crop plants is no better known or understood than are the fundamental geopolitical ideas of Mackinder. It is encouraging, however, to find both these neglects being rectified; in 1951 Vavilov's writings became available in English (*The Origin, Variation, Immunity and Breeding of Cultivated Plants*, published by Chronica Botanica), and by a coincidence the Royal Geographical Society of London reprinted two of Mackinder's key papers as a half-crown pamphlet almost simultaneously.

Just published in Britain is a new economic botany book entitled *Plants for Man* by Robert W. Schery (Allen & Unwin, £3 10*s*.), which deserves a wide readership. Certainly the author, who has been associated with Washington University and the Missouri Botanical Gardens, has produced a valuable and interesting volume by bringing together what he calls 'the fundamental gleanings' of an immense, scattered and usually uncorrelated field. My only regret about the book is that he did not give as references more of his sources of information, for such references would have rendered this work of 564 pages even more valuable. (This deficiency can be met by consulting Albert F. Hill's excellent *Economic Botany*, published by McGraw-Hill, which has a comprehensive bibliography.)

At the beginning of the book there is a chapter which discusses the history of man's economic interest in plants. This brings out the basic fact that economic botany is, of course, as old as man himself. Written records go back beyond 4000 B.C. and we know, for instance, that the palm and fig were valued plants as long ago as 4271 B.C. Flax has been found in the tombs of ancient Egypt, indicating that there was a textile industry based on this fibre plant at least 4000 years ago. In China elaborate types of paper were being made while Europe was still a barbaric region.

The Egyptians brought back many new plants from their military campaigns in Mesopotamia. The reliefs in the Great Temple of Thutmose III at Karnak (which was built on the ruins of Thebes) show many plants which were collected by Thutmose during his Syrian campaigns; 275 species are represented, some of them being identifiable with certainty, e.g. the pomegranate and *Dracunculus vulgaris*. The date of this famous 'herbal in stone' is around 1450 B.C.

Facts about useful plants were recorded by the Greeks. One of Aristotle's pupils, Theophrastus (370–*c.* 285 B.C.), produced a book called *Enquiry into Plants* and Aristotle himself recorded a few facts about plants of interest to his era. A contemporary Greek coin (see Fig. 1) is interesting for it shows an unmistakable barley ear.

The first century A.D. brought two important botanical works—the *Natural History* of Pliny the Elder, and *De Materia Medica* written by his Greek contemporary, Dioscorides.

Schery explains in his book that the majority of Greek and Roman writings stressed the medicinal or supernatural powers of strange 'drug' plants, while disregarding as unworthy of comment—a matter only suitable for the attention of slaves—agriculture and cultivated plants. He suggests that possibly the neglect of the important economic crop plants and the soil in which they grew was a contributory factor in the decline of the great Greek and Roman empires. Certainly the wheatfields of Italy and Greece, which were once the 'breadbasket' of empire, have since been superseded by those of the Ukraine and of various parts of the New World.

So far as we know, the Middle Ages in Europe saw but slight advances in the study of economic plants, though populations expanded and agriculture was, in times of backwardness as in those of progress, an essential art. The great interest in the medical and supposed supernatural virtues of plants continued, giving rise to numerous herbals which expounded the doctrine of signatures. (This held

that plants were created expressly for man's use, an idea which had been expressed by Pliny the Elder, and that the Creator, albeit sometimes cryptically, so designed a plant that its appearance reflected the use to which it could advantageously be put; thus the walnut, with convolutions resembling those of the human brain, was used as a nerve tonic, while the toothwort or pomegranate, endowed with a resemblance to teeth, was enlisted as an aid against oral discomfort.)

There was, one presumes, some powerful social reason for the emphasis being put upon the medicinal virtues of plants rather than upon their use as food. Was it that disease was a far greater source of suffering than hunger? This question is one which would assuredly repay a little historical research.

The first botanical books were certainly books concerned with drug plants. Dioscorides' herbal and similar Greek works went into Syriac and Arabic, and so reached Spain. Another classic was the herbal of Apuleius (*c.* A.D. 400) which appears to have been translated into Anglo-Saxon about A.D. 1000 and a manuscript copy of this book dating from the middle of the 11th century can be seen in the British Museum. In the following centuries the herbals became more elaborate and their illustrations more beautiful and accurate. The accent was still however upon the medicinal uses of plants, a bias which affected the study of botany for a very long time. For this reason most of the early botanic gardens were started as *physic* gardens; an example was the famous Chelsea Physic Garden, which still exists.

The extension of botany to cover other aspects of the plant world was to follow when many new plants were collected by explorers from Europe and the period of colonial expansion began. Physic gardens became botanical gardens, and new economic plants were introduced. One recalls, for instance, the famous private garden maintained by George Clifford (a burgomaster of Amsterdam and a director of the Dutch East India Company) which interested Linnaeus far more than did the Amsterdam Physic Garden; this garden contained many tropical plants of great botanical interest, and it was here that Linnaeus achieved the rare distinction of coaxing a banana plant into flower. This was the period when men like Sir Joseph Banks were organising expeditions to collect plants of scientific and possible economic interest, and when the foundations of the modern herbaria were being laid.

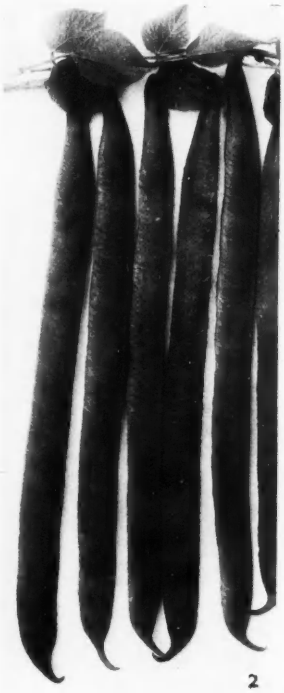
Quite a long time was to elapse before a really significant book dealing with economic plants was to emerge from all this activity. This was the *Origin of Cultivated Plants* (1882) by the Swiss botanist, de Candolle. This work was the first ever to attempt to determine the ancestral form, region of domestication and history of most of the important cultivated plants. His thesis was that the various kinds of crop plants could be traced back to wild ancestors represented by species still in existence and still recognisable. He considered in all 247 ancestral species, and of them he decided that only seven had become extinct.

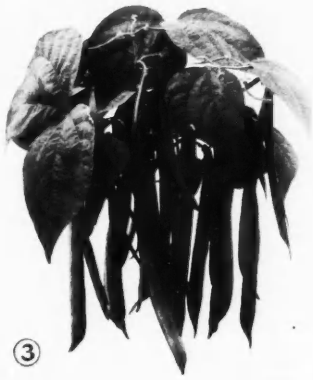
N. I. Vavilov (1885–1942) was to become the de Candolle of the twentieth century. Vavilov and his large team of workers made "a geographical survey of the genetic variation in the staple crop plants of the world", to quote C. D. Darlington's phrase. They then found that each plant showed a centre of diversity, which Vavilov argued was the *centre of origin* of the cultivated 'species'. In this way he related all the major crop plants to eleven or twelve centres of origin. Another important point in Vavilov's theory is this: "a cultivated or wild species will (if natural selection plays any part) come to show a local diversity related to its ecological diversity and this in turn will always be greatest in the mountain-and-valley regions nearest the equator" (C. D. Darlington in his introduction to *Chromosome Atlas of Cultivated Plants*, Allen & Unwin, 1945). Some of Vavilov's generalisations have merited modification in the light of more recent research, but as Schery so rightly says "economic botany is indebted to Vavilov for many basic principles that are still bearing fruit in awakened interest in, and expanding lines of inquiry concerning, domesticated plants".

Schery lists some of the more significant books on economic botany which appeared between 1850 and the modern day. One finds that almost the only books in this list which are of any use to the non-specialist are two old books by T. C. Archer (*Popular Economic Botany*, London, 1853; and *Profitable Plants*, 1865). A recent popular book of merit he mentions is *The Story of Plants and Their Uses to Man*, by John Hutchinson & Ronald Melville (London, Gawthorn, 1949). The one beautifully illustrated book on the subject is Warburg and Brand's *Kulturpflanzen der Weltwirtschaft* (Leipzig, about 1908). Two periodicals devoted exclusively to this subject exist; they are *Economic Botany* published in New York, and the British magazine *World Crops*, published in London by Leonard Hill.

In his chapter on food plants Schery describes Vavilov's main 'centres of origin' of the staple domesticated plants. He goes on to explain how in each ancient culture centre a few food plants were basic to the economy of the individual civilisation. Thus in Mexico and southward, maize was by far the most important food plant; in the middle Andes (where parts of Bolivia and Peru are now demarcated) the potato was pre-eminent, although maize, beans and other foodstuffs were of considerable secondary importance. The cereals—wheat, barley, rye and oats—were most important in the Mediterranean basin, Asia Minor and S.W. Asia, whereas India and China were the domain of rice.

It is important to realise that practically no important domesticated plants or animals were common to both hemispheres, the coconut and the dog perhaps offering exceptions. But in the era of expansion and colonisation following the Middle Ages, food plants were spread by man from one corner of the world to another. The origins of the various crops thus became confused; for instance, the French thought maize came from Turkey and named it *blé de Turquie*; it probably did, but only after it had first reached there from the New World. Similarly the Incan potato reached North America via Europe and became known as the '*Irish* potato'. Many plants were transplanted from one continent to another during the period when Spain, Portugal, Holland and England were jockeying for position in order to gain control of the all-important spice trade (which involved not only spices, but also drugs and sugar); as Schery puts it, "never before this era of travel





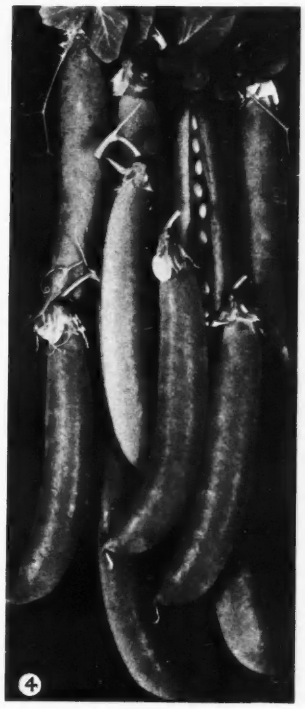


FIG. 2. Scarlet Runner bean, variety 'Prizewinner'. Prior to Columbus, this bean was the exclusive ward of the New World Indians. By 1492 this bean has spread from Peru to New England, along with the Lima bean and the Kidney bean. (*Sutton & Sons photograph*).

FIG. 3. The Kidney bean (otherwise known as the Dwarf or French bean) variety, Sutton's 'Early Giant'.

FIG. 4. The Garden pea (*Pisum sativum*); variety Sutton's 'Improved Peerless'. This pea had its main centre of origin in middle Asia, but there are other areas in which it developed—i.e. the Near East and Ethiopia. First grown for its dry seed, this is the culinary pea that is commonly called the 'English pea' in America; probably the Normans brought it to England though it was a rare delicacy in France up to the end of the 17th century.

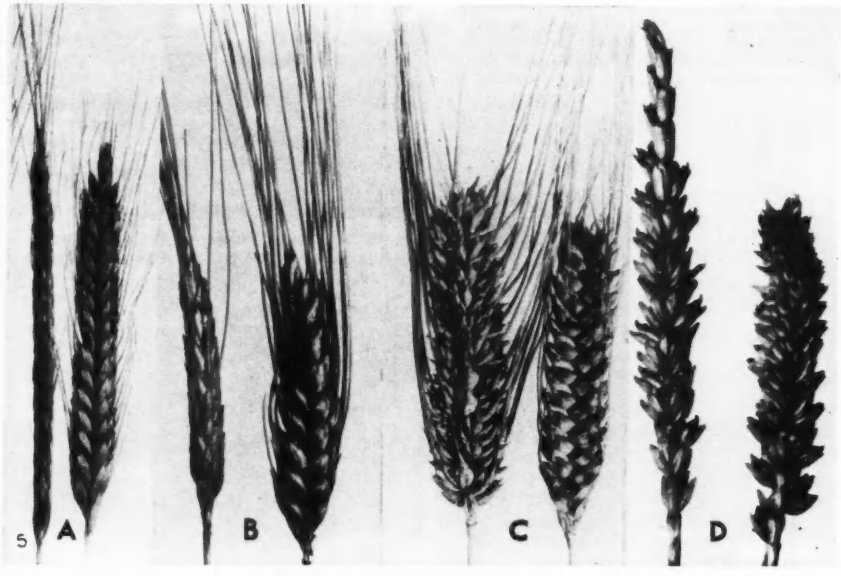


FIG. 5. The ears of different kinds of wheat with 2*x*, 4*x* and 6*x* chromosomes. A. Front and side view of Small Spelt (2*x*). A primitive wheat with grains the size of grass seed. B. Front and side view of Macaroni Wheat (4*x*). C. Front and side view of Rivet Wheat (4*x*). D. Front views only of two contrasting Bread Wheats (6*x*).

Note that the high yielding Rivet has larger ears than Bread Wheat. The superiority of D over B and C, largely a matter of grain quality, cannot be shown in photographs. The original 4*x* wheat from which D was derived was much inferior to types B and C.

A, B and C are reproductions from "The Wheat Plant", *by J. Percival, 1921. D is original.*

FIG. 6. Cork is a plant product of great antiquity: it was used by the Romans and Greeks. A cork oak (*Quercus suber*) is here seen being stripped of its outer bark (the 'corkwood') in Spain: there are nearly 4 million acres of cork forests, over a million of them being in Algeria.

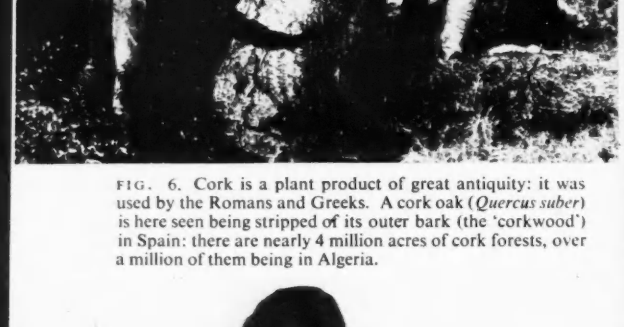


FIG. 7. No wild ancestor of rice has yet been discovered: it was domesticated very early, presumably in the Far East. Thousands of strains are known today. Ninety-five per cent of the world's rice is produced and consumed in the Orient. (*Photo from Ritchie Calder's, "Men Against the Jungle", published by Allen & Unwin.*)

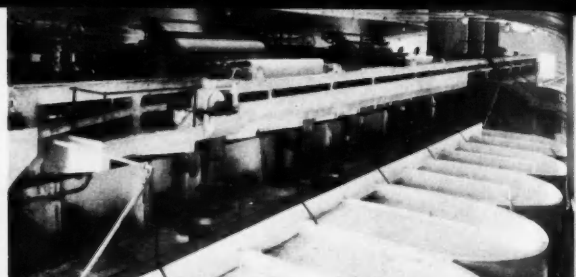


FIG. 8. Wood is a class of plant product for which a myriad uses have been developed. Wood pulp is important in many industrial processes (e.g. paper and Rayon manufacture). (*Courtesy, Swedish Embassy.*)

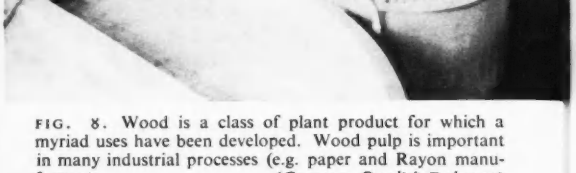


FIG. 9. Many drugs are derived from plants; ergot, a fungus that infests rye, can now be cultivated on the field scale. The sclerotia (here seen germinating) are harvested for medicinal use. (*From Ramsbottom's "Mushrooms & Toad-stools", Collins, 1952.*)

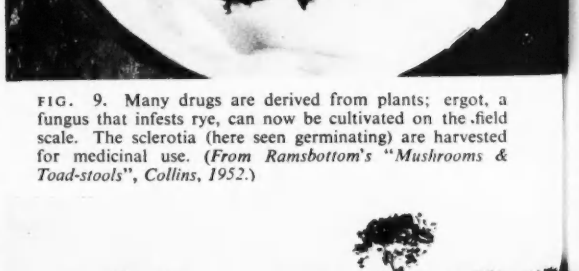


FIG. 10. Flax is one of the oldest fibre plants on which a textile industry was based. The photo shows flax being pulled on an Ulster farm.

which a
nportant
n manu-
mbassy.)

ergot, a
the field
harvested
rooms &

which a
ng pulled

had man been so adept in altering the ecology of the globe and today we grow indiscriminately Old World plants in the New World and New World plants in the Old, side by side with those native to each area".

Schery has some interesting things to say about the food plants of North America before the coming of the white man. Many Indian tribes carried on an agriculture of greater or less complexity, but even these relied to some extent on wild plants. The hunting tribes depended entirely upon wild plants for their limited vegetable fare. The chief cultivated plants were maize, beans, pumpkins, squashes and sunflowers. In addition these Indians ate nuts and fruits; wild herbs provided them with greens and vegetables; bulbs and tubers were used in making meal or as seasonings. They ground the seed of wild grasses into flour. According to Schery, the North American Indians used between one and two thousand wild species as food plants.

The Indians' beans have added variety to the European diet. 'Kidney bean' (*Phaseolus vulgaris*) was the term applied in England in 1551 to distinguish the American 'common bean' from Old World beans; in Britain this popular bean is more usually known as the 'French bean' or 'dwarf bean'. A Peruvian origin is generally attributed to both the Scarlet Runner, *Phaseolus coccineus*, and the Lima bean, *P. lunatus*, though the latest evidence suggests that the latter may have originated in Guatemala; its name, of course, derives from the fact that early European explorers encountered this bean—which is commonly called the 'Butter bean'—in Lima. Beans were grown by the Indians to supplement their maize diet. It was their general practice to grow climbing beans among the maize plants, which provided excellent support for the climbers.

The Indian tribes which inhabited the North American forests used to rely to a large extent on oak acorns, which they pulverised and then leached in streams for several days to remove the bitter flavour. The acorn meal was then fried in grease or oil to provide a tasty and nutritious dish.

Schery states that in their period of New World hegemony the Indians domesticated more than twenty species that are now important world crops, whereas the white man, in his 450 years of New World occupancy, has not taken a single important food plant from the wild. (Though a start in the right direction was made by Luther Burbank when he bred a spineless cactus, which could prove a valuable crop in the arid regions of the world where practically nothing else can be grown.)

In Europe the staple crops are potatoes, wheat, oats, rye, barley and maize. Actually in northern Europe the diet is less than half cereals and potatoes; animal and dairy products, fats and oils, sugar, fruits and vegetables make up almost as large a proportion. But in the Balkans cereals and potatoes account for about three-quarters of the diet. Europe has to import food to support her dense population, but the continent considered as a whole manages to produce about four-fifths of her food. Nearly half of Europe's land area is arable.

It is interesting to consider the origins of Europe's staple crops. The potato is, of course, South American; at the moment it is not possible to be more specific than to say it originated in the Andean region of that sub-continent.

It is a curious fact that the potato has never become popular in the Orient; the Japanese have known it for about two centuries, but have done little with it, preferring rice and the sweet potato—which belongs to a quite different family, the Convolvulus family in fact. The confusion over the name probably arose through corruption of the native name *batatas* for the sweet potato, whose Latin name is *Ipomoea batatas*.

The derivation of *wheat* is a complicated story. It is known that bread wheat was being grown in the Nile Valley by 5000 B.C.; in the Euphrates and Indus Valleys by 4000 B.C.; in China by 2500 B.C.; and in England by 2000 B.C. The evidence suggests diffusion from Mediterranean centres of domestication, and corresponds with the general spread of civilisation as evidenced, for example, by the use of wheel or cart. It was Vavilov's belief that soft wheats originated near the mountains of Afghanistan, durum wheats from North Africa and einkorn from Asia Minor. (*See* Dr. A. J. Bateman's article about the pedigree of wheat in DISCOVERY, 1949, pp. 278–81.)

The origin of *oats* is somewhat obscure, but it is probably polyphyletic. Its domestication is usually considered to have centred in northern Africa, the Near East and temperate Russia—and fairly recently, perhaps as late as 2500 B.C. The common cultivated species (*Avena sativa*) is not known wild, although it is frequently encountered as an escape.

The wild ancestor of rye too has never yet been found. Possibly it was domesticated from the wild rye (*Secale montanum*) of the Mediterranean region, although some experts think *S. anatolicum* of S.W. Asia was a more likely progenitor. Commercial rye (*S. cereale*) is believed to be of more recent origin than most cereals, for besides its similarity to wild forms (forms intermediate between the cultivated and the wild species are not uncommon), no traces of rye have been found either in Egyptian ruins or Swiss lake dwellings. It was, however, known to the Greeks and the Romans.

Barley on the other hand is one of the oldest of cultivated cereals. It was used as food for man and as fodder for beasts in ancient Egypt, and in China around 2800 B.C. It is presumed to have been first domesticated in S. W. Asia, where two wild barley species can still be found. These are *Hordeum spontaneum* and *H. ithuburense*; the former may have been the ancestor of the two-row barleys, the latter of the six-row types.

This brief article gives no more than a hint of the kind of information which *Plants for Man* contains. There are plenty of good maps and statistics for those who are interested in the size of, say, the rice crop or the wheat crop in particular parts of the world. Schery discusses economic plants in general and not just food plants. There are over a hundred pages, for example, on forest trees and their multifarious uses, and there are good chapters on the following themes: latex products (rubber, etc.); pectins, gums and resins; tannins and dyes; essential oils for perfumes, flavours and industrial uses; medicinals, insecticides and herbicides; tobacco; vegetable oils, fats and waxes; sugars and starches; beverage plants; micro-organisms (including penicillin production) and miscellanea. An expensive book, perhaps, but certainly it is good value for the price.

Far and Near

Britain's First 'Breeder' Pile Working: Zephyr goes into operation at Harwell

Zephyr, the zero energy fast reactor at Harwell, became critical for the first time on February 5, 1954. This is the first fast-neutron reactor to be built in Britain. The objects of Zephyr are to obtain operating experience with a fast reactor and to gain information (e.g. about control systems, nuclear constants and materials and methods of reactor construction) which can be obtained only by the actual operation of a reactor. This information will be of major importance to the design work on an experimental power-producing fast breeder reactor which is being undertaken jointly by Harwell and Risley.

The fast reactor has characteristics which make it likely that most of the uranium atoms in natural uranium can be consumed by the breeding process. Consequently, if this type of system can be developed, a nuclear electricity generating system should operate with a much smaller supply of fuel than in the case of natural uranium or slightly enriched uranium thermal fission reactors. The advantages of fast reactors are therefore bound up with the cost and availability of uranium ores.

Reactors previously built and now in use in Britain—two at Harwell and two at Sellafield—use uranium rods enclosed in graphite which acts as a moderator to slow down neutrons produced by fission. Plutonium is created by such piles and those at Sellafield were built for this purpose, but the principle of breeding is to create more fissile material than is consumed.

The construction of a fast reactor requires fissile material that is pure, or nearly pure, so the construction of Zephyr could not be undertaken until this material was available. The fuel used is, in fact, plutonium enclosed in a metal can. The core of a fast reactor is very small, and in the case of Zephyr this is only about the size of a top-hat. It is surrounded by a more massive envelope or blanket of uranium which either reflects back any neutrons escaping from the core or absorbs them so as to produce fresh plutonium. In this way very few neutrons are wasted.

The designation '*zero energy*' means that the reactor is to be operated at a very low power level so that it will not get highly radio-active and will not require cooling. As a result it should be possible to make modifications to the reactor from time to time in the light of experience which has been gained.

The design of Zephyr, in which special attention has been given to safety, has been the responsibility of the Reactor Physics Division at Harwell. They have had assistance with components from nearly every other Division and especially from the Metallurgy and Electronics Division. The detailed design and construction of the reactor was undertaken by the Reactor Engineering Division and the main workshops at Harwell. The safety mechanism was designed and constructed by an outside consultant, Mr. Frazer-Nash, of Kingston upon Thames.

An Atomic Battery

The world's first atomic battery converting nuclear energy directly into electricity was successfully tested in New York recently. The battery converted the rays of a radio-active substance into a thin but distinct squeal in an earphone. Scientists of the Radio Corporation of America, which developed the battery, described the squeal as being as significant as Edison's conversion of electricity to light.

The tiny battery—it is the size of a pencil eraser—turns out only one-thousandth of a watt of power, but ten of these atomic batteries could run a modern portable radio for 20 years. David Sarnoff, chairman, said the invention will probably be used in portable and R.C.A. pocket-sized radio receivers, hearing aids, portable short-range transmitters for radio, telegraph and telephone communications and radio navigational beacons. He added that if the promise of the atomic battery is fulfilled "the power plant of the future would have only an atomic generator connected directly to cables carrying to far-flung communities the power needed for the purposes of peace. Boilers, engines and electric generators would become elements of the past."

The Atomic Energy Authority Bill

The Parliamentary Bill setting up the United Kingdom Atomic Energy Authority has been published by H.M. Stationery Office, price 9*d*.

Pamphlets of Scientific Interest

The latest scientific book catalogue published by Lewis's of Gower Street covers the chemical industry (including metallurgy and photography). This is obtainable on application to H. K. Lewis & Co. Ltd., 136 Gower Street, London, W.C.1.

* * *

A leaflet giving details about this year's *Endeavour* essay competition can be obtained from the Assistant Secretary, British Association, Burlington House, London, W.1. (mark envelope *Endeavour Essay*).

* * *

The Agricultural Research Council has published a booklet about their training grants, studentships and fellowships; this is obtainable from: The Secretary, A.R.C., 15 Regent Street, London, S.W.1.

* * *

A new publication of 28 pages issued by the Publicity Dept. of Henry Wiggin & Co. Ltd., Thames House, Millbank, London, S.W.1 is devoted to the subject of "Nickel Alloy Spring Materials". This is a revised version of a booklet first published two years ago and it contains data on Nimonic 90, an alloy which is rapidly winning acceptance for springs operating at high temperatures.

* * *

The B.D.H. Laboratory Chemicals Group, Poole, have issued a leaflet about their standard coloured absorbent paper discs ('Fordisc') for use in bacterial sensitivity tests. B.D.H. are producing, in sets of five bottles each containing 100 discs of a different colour, or in single bottles of one colour, sterile discs (not impregnated) for use in the assay of antibiotics in body fluids, as in the Edinburgh Standard Disc Diffusion Test, and other bacterial sensitivity tests by the diffusion technique. The very simple procedure will be of particular value to hospitals where large numbers of routine sensitivity tests are conducted. The leaflet describing the method, with standard graphs relating zones of inhibition to antibiotic sensitivity, is available, free on request.

* * *

The British Council has published a booklet giving details of over 100 scholarships offered to British students by 16 foreign countries for study abroad during the academic year 1954–5. The scholarships are intended mainly for graduates and undergraduates of British universities, but some are also open to those with non-academic professional qualifications. The awards generally provide for free tuition and maintenance, and are tenable for periods varying from four to twelve months. (The closing date for receipt of applications varies for each country, the earliest date being March 8.)

Full particulars and application forms may be obtained, on receipt of a stamped addressed foolscap envelope, from any British Council office in the United Kingdom; or from The Controller, Education Division, The British Council, 65 Davies Street, London, W.1.

U.S. Research Fellowships for Young Scientists

The first appointments to United States (F.O.A.) Research Fellowships have been made by the National Academy of Sciences, Washington, on the nomination of the Royal Society, as follows:

G. N. Lance, B.Sc., Ph.D., of Dorking, employed by Hawker Aircraft Ltd., to work on problems in unsteady supersonic aerodynamics at the University of California under Professor John Miles.

S. H. Parker, B.Sc., of University College, Leicester to carry out research in physical-organic chemistry at the Massachusetts Institute of Technology under Professor Gardner Swain.

The Fellowships were instituted in 1953 with funds provided by the United States

Government, through its Foreign Operations Administration. They are intended to enable a number of outstanding young scientists from Europe to work in the United States for up to two years in order to study and gain experience in American research institutions.

N.R.C. Scholarships increase in Value

The Science and engineering scholarships which the National Research Council of Canada award have been increased to the following values: bursaries, $800; studentships, $1100; fellowships, $1400. A student awarded any of these scholarships will be eligible, upon recommendation of his research supervisor, for a supplementary stipend for the summer months, now amounting to $800. Value of special scholarships has been increased to $1900. Post-doctorate overseas fellowships remain unchanged. Inquiries regarding these awards should be addressed to: The Awards Officer, National Research Council, Sussex Street, Ottawa 2.

Night Sky in March

The Moon.—New moon occurs on March 5d 03h 11m, U.T., and full moon on March 19d 12h 42m. The following conjunctions with the moon take place:

March

11d 13h	Jupiter in conjunction with the moon	Jupiter	3°	S.
23d 02h	Saturn ,,	Saturn	8°	N.
26d 15h	Mars ,,	Mars	3°	N.

The Planets.—Mercury is in inferior conjunction on March 1 after which it is a morning star, rising at 5h 35m and 5h 10m at the middle and end of the month respectively, but is too close to the sun to be favourably seen. Venus is an evening star, setting at 18h 10m, 18h 55m and 19h 45m on March 1, 15 and 31 respectively. Nearly all the illuminated portion of the disk is visible and the stellar magnitude remains −3·4 during the month. Mars, a morning star, rises at 2h, 1h 40m and 1h 15m on March 1, 15 and 31 respectively. The planet increases in brightness during the month, its stellar magnitude varying between 0·8 and 0·2. This is due to the decrease in its distance from the earth—from nearly 117 million miles on March 1 to 90 million miles on March 31. Jupiter sets in the early morning hours—at 2h 35m, 1h 45m and 0h 50m on March 1, 15 and 31 respectively. Its stellar magnitude is about −1·8 during the month but it is slowly decreasing in brightness owing to its increasing distance from the earth. On March 1 this distance is 456 million miles, and on March 31 it is a little over 500 million miles. Saturn is an evening star, rising at 23h, 22h and 20h 55m on March 1, 15 and 31 respectively. Its stellar magnitude varies from 0·6 to 0·5 and from the increase in brightness, which increases with decreasing magnitude, we could infer that the distance between Saturn and the earth is decreasing. On March 1 the distance between the two planets is 860 million miles, and on March 31 it is 830 million miles, the decrease of 30 million miles accounting for the increase in Saturn's brightness, though it is doubtful whether any readers will be able to detect this increase. Although the planet can be easily identified in the constellation Librae and a little N.W. of its brightest star α, owing to its S. declination it will not rise very far above the horizon and even when it crosses the meridian at 4h, 3h and 1h 55m on March 1, 15 and 31 respectively, it will be less than 27° above the horizon. Readers will, of course, understand that these figures refer to the latitude of Greenwich. Vernal equinox takes place on March 21d 04h.

Standardised Names for Australian Plants

Standardised Plant Names, the C.S.I.R. Bulletin (No. 156) issued in 1942, was an attempt to establish common names for all the more important Australian pasture plants and weeds. This has now been revised and re-issued as Bulletin No. 272, which runs to 132 pages and is available from the Commonwealth Scientific & Industrial Research Organisation, Melbourne.

Dr. K. S. Dodds, New Director of John Innes

DR. K. S. DODDS has succeeded Professor C. D. Darlington, F.R.S., as director of the John Innes Horticultural Institution. Dr. Dodds is well known for his researches on the disease resistance and cytogenetics of wild and cultivated potatoes at the A.R.C. Potato Genetics Station, Cambridge University.

* * *

SIR GEORGE ALLEN, C.B.E., from Malaya, has been appointed secretary of the British Association in succession to Mr. David N. Lowe.

* * *

MR. PATRICK JOHNSON, who recently resigned from Power Jets (Research & Development) Ltd., to extend the scope of his activities in technological consultancy, has been appointed to develop the European interests of Solar Aircraft Company, of San Diego, California. In this appointment, he will maintain his connexion with gas turbines, which originated in his early association with Sir Frank Whittle, as the American firm are manufacturers of gas turbines and their components. Mr. Johnson remains free to serve the various other organisations and committees of which he is a member, and to be available as an adviser to Power Jets and others.

LETTER TO THE EDITOR

The Constantinesco Torque Converter

Sir,

In your issue of November 1953, in the article entitled "Automobile Development", Mr. W. Harold Johnson refers to the Constantinesco torque converter and suggests that the reason why it "just did not catch on" was that the inventor would not produce or license his torque converter for an existing or conventional car, but insisted on offering it with his vertical twin two-stroke engine. He further remembers that he was almost swamped by wonder as to when he would be actually thrown out of the car by the vibration of the engine!

Your readers may be able to judge the value of such damaging and untrue statements appearing in a serious publication like DISCOVERY when they could ascertain the facts from better records than from the reminiscences of Mr. Johnson.

Enclosed I send you, Sir, a copy from an article entitled "The 5 H.P. Constantinesco Chassis" from *The Automobile Engineer*, December 1926, in which qualified and responsible expert opinion is expressed in terms which flatly contradict Mr. Johnson's statements. I quote:

"*On the road the car performs precisely as foretold by the inventor long before the construction of the vehicle. In starting away the throttle pedal is fully depressed, instead of gradually as with the normal car. In the process of acceleration, which is rapid, there is a little vibration, but it is of high frequency, and as soon as the vehicle has gathered speed the travel is perfectly smooth, and there is an entire absence of mechanical noise or vibration. The two-stroke two-cylinder engine is noisy in the matter of its exhaust, and usually is difficult to balance, but mechanically the vehicle is perfectly sweet and smooth.*"

I enclose also a photograph of an orthodox 4-cylinder engine of 1000 c.c. coupled to my torque converter. Many other types were made for cars, rail-cars, trucks, diesel engine starters and other industrial applications coupled with either orthodox engines of one, two, four or six cylinders or electric motors.

One of the torque converter self-propelled rail-cars on the Continent weighed some thirty tons and the only power available was supplied by two 4-cylinder orthodox Ford car engines of 3 litres each. The car travelled at 40 miles per hour and carried sixty passengers, the speed varied automatically according to the gradients and the whole control was only a Bowden wire cable to the carburettors and, of course, the Westinghouse brakes.

So much for Mr. Johnson's statement that the inventor would not produce or license his torque converter for an existing or conventional car.

I hope that this matter will be given full publicity as a matter of public interest and also in order to minimise, if possible, the damage already done to my interests by the above unjustified publication.

Yours faithfully,

G. CONSTANTINESCO

Oxen House, Torver, Coniston, Lancs.

GOVERNMENT PUBLICATIONS

SURGERY

MEDICAL HISTORY OF THE SECOND WORLD WAR

edited by

SIR ZACHARY COPE

A comprehensive outline of the evolution of the main technical and therapeutic improvements which will for ever make the Second World War surgically memorable. Illustrated. 80*s*. (81*s*. 6*d*. by post)

BRITAIN'S ATOMIC FACTORIES

The Story of Atomic Energy Production in Britain

by K. E. B. JAY, B.Sc., A.Inst.P.

Describes the creation and building of an entirely new industry in less than five years—an achievement which will stand comparison with any other in the history of British industry. Illustrated. 5*s*. (5*s*. 2*d*. by post)

HER MAJESTY'S STATIONERY OFFICE

York House, Kingsway, London W.C.2; 423 Oxford Street, London W.1 (Post Orders: P.O. Box 569, London S.E.1); 13a Castle Street, Edinburgh 2; 39 King Street, Manchester 2; 2 Edmund Street, Birmingham 3; 1 St. Andrew's Crescent, Cardiff; Tower Lane, Bristol 1; 80 Chichester Street, Belfast; *or through any bookseller*.

THE CHEMICAL REVOLUTION

by A. & N. L. CLOW

Economic history and chemical technology written for the layman as well as the scientist.

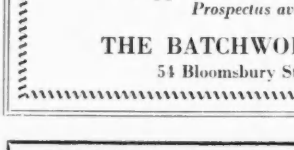
696 pp. 126 illus. 50s. net

Prospectus available

THE BATCHWORTH PRESS

54 Bloomsbury Street, WC1

CHARLES PORTASS & SON



3" x 12½" MODEL "S"

As illust. less centres £23.10.0

3" x 18" between centres ... £26.0.0

3½" x 12½" " " ... £26.0.0

3½" x 18" " " ... £28.10.0

Rear Countershaft Unit. Flat or Vee £4.15.0. Pair Vee Belts 19s. 6d. Pair

No. 1 centres 12s. 6d.

PRECISION -00025

3" x 11"

P.D.5 £29.10.0

Mod. C 3" x 10

£13.17.6

Stamp please. Dept. D Buttermere Works, Sheffield 8

The SCIENCE READER'S COMPANION

The constant and ever increasing use of scientific words and terms is daily becoming more evident, and the average person today is not indifferent to the role science is playing in his life. He is displaying a lively and deeply concerned interest, and is keen to understand the far-reaching changes which the advances of science are producing. It is the purpose of this companion to serve this new and significant interest by giving clear and explicit definitions of words likely to be encountered by the non-specialist reader and student.

WRITE FOR ILLUSTRATED LEAFLET TO THE ADDRESS BELOW

FROM YOUR BOOKSELLER 15/-

WARD LOCK

WARD LOCK & CO. LTD., DEPT. (D), PRETORIA RD., LONDON N.18

Introduction to

Nuclear Engineering

Richard Stephenson

Consulting Editor

This is the first book to bring together the many unique engineering problems encountered in the nuclear engineering field. Its main purpose is to afford engineers, who are taking, or have completed a standard engineering curriculum, with the engineering problems encountered in the engineering field. It includes details concerning reactor theory, radiation shielding, reactor materials, reactor control, separation of stable isotopes, chemical processing of radioactive materials, remote handling equipment and special engineering problems. Numerous examples and problems are illustrated throughout and references to declassified reports show where more detailed information can be found

Approx 500 pages. Price approx 53s 6d

Available shortly from your usual Bookseller

A Physics sectional list covering all recent publications will be forwarded on request

Publicity Department
McGraw-Hill Publishing Company Ltd
McGraw-Hill House London EC4

THE BOOKSHELF

Britain's Atomic Factories by K. E. B. Jay, of the Division of Atomic Energy, Ministry of Supply. (*London, H.M. Stationery Office, 1954, 100 pp., 5s.*)

Report on the Atom by Gordon Dean (*London, Eyre & Spottiswoode, 288 pp., 16s.*)

These are new books about atomic energy which readers will find worthy of their attention. *Britain's Atomic Factories* gives a clear picture of the work which goes on in the Springfields uranium factory, the plutonium plant at Windscale and the U235 gaseous diffusion plant at Capenhurst.

The other is written by Gordon Dean who succeeded David Lilienthal as chairman of the U.S. Atomic Energy Commission and held this post for three years until his resignation in June 1953. A lawyer by training, he reviews all the salient facts about American atomic energy work in a way which will interest all who are not specialists in this sphere. Necessarily he cannot go into the finer technical details, but one chapter (entitled "The production line: ore to bombs") is probably the most vivid attempt so far to explain simply to the general reader the extraction of uranium, its refining and conversion into plutonium, and the concentration of U235. (Readers will find it useful to have by them as they read this chapter the flow-sheets printed in *Britain's Atomic Factories*, which summarise the various steps involved in these processes with crystal clarity.) Mr. Dean is particularly good where he deals with such things as the climate of opinion which formed the background to the passing of the U.S. Atomic Energy Act of 1946 that put atomic energy development under the control of a civilian agency—the A.E.C. with its five commissioners; two committees linking the commission with Congress and the three armed Services respectively; and the nine-member General Advisory Committee which advises on scientific and technical matters. The book is unique in that it brings together all the key historical data about the American atomic energy project. Possibly the most ingratiating feature of Mr. Dean's work is the keen sympathy he shows for the hopes and aspirations of the scientists with whom his duties as A.E.C. chairman brought him in contact, and it is therefore not surprising to find that men like Dr. Robert Oppenheimer (the first head of Los Alamos and first chairman of the A.E.C.'s General Advisory Committee) should recommend this book. There is nothing parochial about this work, its author being well aware of the contributions which the scientists and engineers of Britain and other countries have made and continue to make in this field. If at times the reader becomes a little irritated by a rare touch of naïveté, one cannot help tempering one's reaction with the thought that most of us have said or written at some time or other something that later seemed to be rather naïve in the light of later events; in any event his naïveté where it does occur is surely only the reflection of the well-intentioned thoughts of a good-hearted man who claims no special omniscience or special insight in matters which are immensely complicated and capable of conjuring up a not very remote prospect of an atomic Armageddon if events are allowed to get out of hand. Sumner Pike, who presided over the A.E.C. as interim chairman in the interregnum between Lilienthal and Gordon Dean, described the commission's job as "somehow revolting"; Lilienthal resigned over the hydrogen bomb issue, and went out of office saying that he had a "visceral feeling that this is wrong": Oppenheimer, who probably deserves the major share of the credit for developing the atomic bomb but who turned his face against the hydrogen bomb project, has summed up the scientists' feelings towards atomic weapons by admitting that a guilt complex had settled upon atomic scientists after Hiroshima because "they had known sin". Gordon Dean has looked as deep into the Pandora's Box of atomic science as any of these men, and it is therefore all the more remarkable that he has been able to produce a book so eminently sane and solid as *Report on the Atom*, though in truth he takes a resigned rather than optimistic view of the future.

It needs to be said that the book is in no way an ephemeral memoir; it will have permanent value for reference purposes, for it gives that authoritative confirmation of a number of press statements which one only half accepted so long as the facts contained in them went unsupported by official statements, and encompasses a surprisingly large number of facts which would otherwise have to be culled from hundreds of newspaper clippings and scores of official documents.

Incidentally, the general reader is probably likely to get much more out of Dean's book than from *Britain's Atomic Factories*, though the two books supplement each other. Flow sheets like those printed in the latter should have been included in *Report on the Atom*, for they are a boon to the general reader in spite of what some publishers think about them.

A Laboratory Manual of Experimental Physics by L. R. Ingersoll, M. J. Martin, and T. A. Rouse (*London & New York, McGraw-Hill Book Co., 1953, 286 pp. 32s.*)

The fact that this is the sixth edition of a text-book first published in 1925 speaks highly of its value to students. In each edition some experiments have been left out to make way for new ones, so there need be no fear that a book nearly 30 years old in its first form is in any sense out of date. As usual with the publishers the production is excellent. The authors are highly qualified and have great teaching experience.

The most extensive of the revisions occurred in the third edition (1932) when 40% of new material was added, and the present one, from which thirteen outmoded experiments have been removed and replaced by seven new ones. It is interesting to speculate, without doing any bibliographical research, on which are the modern experiments inserted. The following can be surmised: the flow of air over an aerofoil, the electric refrigerator as an application of the second law of thermodynamics, the mapping of equipotential surfaces, the thermionic valve, the cathode-ray oscilloscope, the Geiger counter, polarisation utilising Polaroid. This list gives some idea of the scope of a book that does not claim to be very advanced and is in fact designed for students taking general physics or technical physics.

Each experiment is broken down into object, foreword (mainly theoretical), apparatus, procedure, and questions. A student in Britain could well make use of this book to supplement the well-thumbed, mutilated and begrimed manuscript notes still to be found in many a technical college and university college.

C. L. BOLTZ

Luminescence and the Scintillation Counter by S. C. Curran, F.R.S. (*London, Butterworths Scientific Publications, 1953, 219 pp., 32s. 6d.*)

Fifty years ago, the pioneers in what is now called nuclear physics, spent many arduous hours in a darkened room counting the minute flashes of light emitted by a luminescent screen as it was bombarded by α-particles. Today, a wide range of phosphors are being used, together with photo-electric multipliers, to count all kinds of particles at rates as high as several thousands per second. Most of the progress in this method of counting has been made in the last ten years and the author of this book has been responsible for a considerable part of it.

Dr. Curran's book is packed with useful and relevant information, is well supplied with references to the already extensive literature on the subject and yet remains eminently readable.

Briefly, the contents cover the nature and methods of detection of elementary particles, the luminescence of inorganic and organic materials, special methods of phosphor preparation for scintillation counters, the fundamentals and design of secondary emission photo multipliers and finally the electronic circuits evolved for the application of the counters to special problems.

The book can be strongly recommended. It will be of lasting value both as a general introduction to the subject and as a handbook for those directly concerned in any way with scintillation counters.

C.G.A.H.

EARLY MAN

A. H. BRODRICK

The background of a recent 'regrettable incident' and "the survey will be most useful to all who wish to follow the existing course of such discoveries."— *Sunday Times* **18s.**

BASIC NAVAL ARCHITECTURE

K. C. BARNABY
O.B.E., B.Sc., M.I.N.A.

A much revised second edition of this standard work is now available. 35s.

Both books are fully illustrated

HUTCHINSON'S
Scientific & Technical Publications

BOOKS

Telephone: **EUSton 4282**

LARGE STOCK OF NEW & STANDARD BOOKS ON CHEMISTRY—PURE AND APPLIED, PHYSICS, MATHEMATICS, BIOLOGY, PSYCHOLOGY, ENGINEERING, AGRICULTURE. STUDENTS' TEXT-BOOKS FOR ALL SCIENTIFIC EXAMINATIONS SUPPLIED. CATALOGUE ON REQUEST

Please state interests when writing

SCIENTIFIC LENDING LIBRARY

Annual Subscription from 25 shillings

The library covers a wide range of subjects and is invaluable to schoolmasters and students.

Prospectus free on request

THE LIBRARY CATALOGUE revised to December, 1949, containing a classified index of authors and subjects. Pp. xii + 1152. To subscribers 17s. 6d. net. To non-subscribers 35s., postage 1s. 3d. Supplement 1950 to 1952. To subscribers 3s. net; to non-subscribers 6s. net; postage 6d.

SECOND-HAND BOOKS

Large stocks of recent editions of scientific and technical works available
Libraries or small collections purchased

LONDON
H. K. LEWIS & Co. Ltd.
136, GOWER STREET, W.C.1

The first four Interscience Manuals:

STATISTICAL METHODS FOR CHEMICAL EXPERIMENTATION

By W. L. GORE

CONTENTS: Introduction. Statistical Concepts. The Reliability of Estimates. Analysis of Variance. Design of Experiments. Correlation and Regression. Attribute Statistics. Tables, Index to Formulae, Glossary, Bibliography and Subject Index.

1952 $4\frac{7}{8} \times 7$ 221 pages 20 illus. 25*s.*

FIBER MICROSCOPY

A Textbook and Laboratory Manual

By A. N. HEYN

CONTENTS: The Microscope and its Manipulation. Unstained Fiber: Preparation and Examination. Cotton. Flax and Hemp. Ramie and Jute. Whole Fibers: Staining and Mounting. Micrometry. Recording of Observations. Wool and Other Animal Hair Fibers. Hand Sectioning. Rayons. Resolving Power. Silk. Mechanical Sectioning. Hard Fibers; Paper Fibers. Regenerated Protein and Alginate. Synthetic Fibers. Mineral Fibers and Starches. Fiber Identification: Methods. Polarizing Microscope. Special Optical Methods.

1954 $4\frac{7}{8} \times 7$ 419 pages 37 illus., 6 tables 38*s.*

CHEMICAL METHODS IN INDUSTRIAL HYGIENE

By F. H. GOLDMAN and M. B. JACOBS

CONTENTS: Introduction and Sampling. Reagents and Standard Solutions. Determination of Size Distribution of Dusts and Powders. Free Silica. Inorganic Compounds and Gases. Metals. General Methods for Volatile Solvents. Organic Solvents. Miscellaneous Gases, Vapors and Mists. Bibliography. Appendix (Threshold Limit Values for 1952. Conversion Table for Gases and Vapors. Outline of Sampling and Analytical Procedures in Air Analysis). Index.

1953 $4\frac{7}{8} \times 7$ 284 pages 24 illus. 27*s.*

DETERGENCY EVALUATION AND TESTING

By J. C. HARRIS

CONTENTS: Introduction. Screening Tests. Cotton Washing. Cotton Wash Test Methods. Wool Washing. Washing Procedures for Other Fibers. Hard Surface Cleaning. Radioisotopic Tracer Method. Miscellaneous Tests. Index.

1954 $4\frac{7}{8} \times 7$ 220 pages 26 illus., 15 tables 25*s.*

INTERSCIENCE PUBLISHERS LTD.

89–90 Chancery Lane **London, W.C.2**

S

ncepts.
riance.
ression.
rmulae,

25*s*.

ulation.
nation.
Whole
y. Re-
Animal
solving
Fibers;
lginate.
Fiber
oscope.

38*s*.

NE

BS

eagents
ze Dis-
a. In-
General
olvents.
Biblio-
r 1952.
tline of
alysis).

27*s*.

ION

Cotton
Wash-
Hard
Method.

25*s*.

W.C.2